



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
HELIUM ACTIVITY
HELIUM RESEARCH CENTER
INTERNAL REPORT

THERMODYNAMIC PROPERTIES OF A REDLICH-KWONG FLUID

IN THE TWO-PHASE REGION

BY

B. J. Dalton

Robert E. Barieau

BRANCH

Fundamental Research

PROJECT NO.

6902

DATE

February 1969

AMARILLO, TEXAS

#929491043

ID88070888

HD
9660
.H43
M56
1
no. 113

Report No. 113

HELIUM RESEARCH CENTER
INTERNAL REPORT

THERMODYNAMIC PROPERTIES OF A REDLICH-KWONG FLUID
IN THE TWO-PHASE REGION

By

B. J. Dalton and Robert E. Barieau

Branch of Fundamental Research

Project 6902

February 1969

BLM Library
Denver Federal Center
Bldg. 50, OC-521
P.O. Box 25047
Denver, CO 80225

CONTENTS

	<u>Page</u>
Abstract	21
Introduction	22
Acknowledgment	23
Mathematical nomenclature and symbolism	24
The Redlich-Kwong equation of state	26
The pressure-temperature coefficient at constant density	30
The pressure-density coefficient at constant temperature	30
The density-temperature coefficient at constant pressure	30
The second derivative of the pressure with regard to the temperature at constant density	31
The coefficient of compressibility at constant temperature	31
The coefficient of thermal expansion at constant pressure	32
Partial derivatives of X which can be calculated from previously calculated quantities	32
The fugacity function	33
The relative Gibbs free energy	33
The relative Helmholtz free energy	34
The relative entropy	35
The relative internal energy	35
The relative heat capacity at constant volume	36
The relative heat content or the relative enthalpy	36

	<u>Page</u>
The relative heat capacity at constant pressure	37
The second derivative of the chemical potential or Gibbs free energy with regard to the temperature at constant density	39
The difference between the heat capacities at constant pressure and at constant volume	40
The ratio of the heat capacities at constant pressure and at constant volume	40
The velocity of sound	41
The temperature-pressure coefficient at constant enthalpy or the Joule-Thomson coefficient	41
The pressure-temperature coefficient at constant entropy	42
The volume-temperature coefficient at constant entropy	43
The pressure-volume coefficient at constant entropy	44
The second virial coefficient	45
The Boyle temperature	45
The third virial coefficient	45
The Joule-Thomson inversion curve	46
Condition for thermodynamic equilibrium between coexisting phases of a one-component system	47
Method for obtaining the solutions of the functional relationships between the equilibrium reduced densities and the equilibrium reduced temperature of the coexisting phases	49
Coexistence curve of saturated liquid and vapor densities and volumes as a function of temperature	51
Coexistence curve of saturated liquid and vapor densities as a function of pressure	70
Vapor pressure curve	73

	<u>Page</u>
Saturated compressibility factors	80
Temperature coefficient of the vapor pressure curve	87
Temperature coefficients of the saturated liquid and gas densities	95
Temperature coefficient of the rectilinear diameter	106
Saturated fugacity function	107
Saturated relative Gibbs free energy	120
Saturated relative Helmholtz free energies	120
Saturated relative entropies	130
Entropy of vaporization	136
Saturated relative internal energies	136
Saturated relative heat capacities at constant volume	148
Saturated relative enthalpies or relative heat contents	160
Heat of vaporization	166
Saturated relative heat capacities at constant pressure	173
A function related to the heat of vaporization, namely the heat of vaporization per mole of gas collected outside the calorimeter	191
Second temperature derivative of the vapor pressure curve	197
Heat capacity of the saturated gas	202
Heat capacity of the saturated liquid	203
Second temperature derivative of the saturated chemical potential or Gibbs free energy	213
Heat capacity at constant volume with two phases present in the calorimeter and the filling density equal to the critical density	218

	<u>Page</u>
Saturated pressure-temperature coefficients at constant density	220
Saturated pressure-density coefficients at constant temperature	223
Saturated coefficients of compressibility at constant temperature	229
Saturated coefficients of thermal expansion at constant pressure	248
Differences between the heat capacities at constant pressure and at constant volume at saturation	257
Ratio of the heat capacities at constant pressure and at constant volume at saturation	265
Velocities of sound at saturation	272
Saturated Joule-Thomson coefficients	279
Joule-Thomson inversion curve for a Redlich-Kwong fluid . . .	280
Critical isotherm	286
Velocity of sound along the critical isotherm	291
Discontinuity in the heat capacity at constant volume in passing from two phases present in the calorimeter to a single phase	296
References	307

ILLUSTRATIONS

Fig.

1. Redlich-Kwong fluid, saturated densities as a function of temperature	53
2. Redlich-Kwong fluid, saturated densities as a function of temperature near the critical point	55
3. Redlich-Kwong fluid, saturated volumes as a function of temperature	57

	<u>Page</u>
4. Redlich-Kwong fluid, saturated volumes as a function of temperature near the critical point	58
5. Redlich-Kwong fluid, density-coexistence data as a function of temperature	61
6. Redlich-Kwong fluid, volume-coexistence data as a function of temperature	64
7. Redlich-Kwong fluid, density-coexistence data as a function of temperature near the critical point	66
8. Redlich-Kwong fluid, volume-coexistence data as a function of temperature near the critical point	67
9. Redlich-Kwong fluid, coexistence data as a function of temperature	69
10. Redlich-Kwong fluid, coexistence data as a function of temperature near the critical point	71
11. Redlich-Kwong fluid, coexistence data as a function of pressure	75
12. Redlich-Kwong fluid, coexistence data as a function of pressure near the critical point	76
13. Redlich-Kwong fluid, vapor pressure data as a function of temperature	78
14. Redlich-Kwong fluid, vapor pressure data as a function of temperature near the critical point	79
15. Redlich-Kwong fluid, logarithm of the pressure as a function of reciprocal temperature	82
16. Redlich-Kwong fluid, logarithm of the pressure as a function of reciprocal temperature near the critical point	83
17. Redlich-Kwong fluid, saturated compressibility factors as a function of temperature	85
18. Redlich-Kwong fluid, saturated compressibility factors as a function of temperature near the critical point	86

	<u>Page</u>
19. Redlich-Kwong fluid, asymptotic function of the saturated compressibility factors as a function of temperature	89
20. Redlich-Kwong fluid, temperature coefficient of the vapor pressure curve as a function of temperature	92
21. Redlich-Kwong fluid, temperature coefficient of the vapor pressure curve as a function of temperature near the critical point	93
22. Redlich-Kwong fluid, logarithm of the temperature coefficient of the vapor pressure curve as a function of reciprocal temperature	96
23. Redlich-Kwong fluid, logarithm of the temperature coefficient of the vapor pressure curve as a function of reciprocal temperature near the critical point	97
24. Redlich-Kwong fluid, temperature coefficients of the saturated liquid and gas densities as a function of temperature	100
25. Redlich-Kwong fluid, temperature coefficients of the saturated liquid and gas densities as a function of temperature near the critical point	102
26. Redlich-Kwong fluid, asymptotic function of the temperature coefficients of the saturated liquid and gas densities as a function of temperature	105
27. Redlich-Kwong fluid, temperature coefficient of the rectilinear diameter as a function of temperature	109
28. Redlich-Kwong fluid, temperature coefficient of the rectilinear diameter as a function of temperature near the critical point	110
29. Redlich-Kwong fluid, logarithm of the fugacity function, at saturation, as a function of temperature	113
30. Redlich-Kwong fluid, logarithm of the fugacity function, at saturation, as a function of temperature near the critical point	114

Page

31.	Redlich-Kwong fluid, logarithm of the fugacity function, at saturation, as a function of reciprocal temperature near the critical point	116
32.	Redlich-Kwong fluid, the fugacity function, at saturation, as a function of the temperature	118
33.	Redlich-Kwong fluid, the fugacity function, at saturation, as a function of the temperature near the critical point	119
34.	Redlich-Kwong fluid, relative Gibbs free energy, at saturation, as a function of temperature	122
35.	Redlich-Kwong fluid, relative Gibbs free energy, at saturation, as a function of temperature near the critical point	123
36.	Redlich-Kwong fluid, saturated relative Helmholtz free energies as a function of temperature	126
37.	Redlich-Kwong fluid, saturated relative Helmholtz free energies as a function of temperature near the critical point	127
38.	Redlich-Kwong fluid, asymptotic function of the saturated relative Helmholtz free energies as a function of temperature	129
39.	Redlich-Kwong fluid, saturated relative entropies as a function of temperature	132
40.	Redlich-Kwong fluid, saturated relative entropies as a function of temperature near the critical point	133
41.	Redlich-Kwong fluid, asymptotic function of the saturated relative entropies as a function of temperature	135
42.	Redlich-Kwong fluid, entropy of vaporization as a function of temperature	138
43.	Redlich-Kwong fluid, entropy of vaporization as a function of temperature near the critical point	139

	<u>Page</u>
44. Redlich-Kwong fluid, asymptotic function of the entropy of vaporization as a function of temperature	141
45. Redlich-Kwong fluid, saturated relative internal energies as a function of temperature	144
46. Redlich-Kwong fluid, saturated relative internal energies as a function of temperature near the critical point	145
47. Redlich-Kwong fluid, asymptotic function of the saturated relative internal energies as a function of temperature	147
48. Redlich-Kwong fluid, saturated relative heat capacities at constant volume as a function of temperature	150
49. Redlich-Kwong fluid, saturated relative heat capacities at constant volume as a function of temperature near the critical point	151
50. Redlich-Kwong fluid, asymptotic function of the saturated relative heat capacities at constant volume as a function of temperature	153
51. Redlich-Kwong fluid, differences in the saturated heat capacities at constant volume as a function of temperature	156
52. Redlich-Kwong fluid, differences in the saturated heat capacities at constant volume as a function of temperature near the critical point	157
53. Redlich-Kwong fluid, asymptotic function of the differences in the saturated heat capacities at constant volume as a function of temperature	159
54. Redlich-Kwong fluid, saturated relative enthalpies as a function of temperature	162
55. Redlich-Kwong fluid, saturated relative enthalpies as a function of temperature near the critical point	163

Page

56.	Redlich-Kwong fluid, asymptotic function of the saturated relative enthalpies as a function of temperature	165
57.	Redlich-Kwong fluid, heat of vaporization as a function of temperature	170
58.	Redlich-Kwong fluid, heat of vaporization as a function of temperature near the critical point	171
59.	Redlich-Kwong fluid, asymptotic function of the heat of vaporization as a function of temperature . . .	174
60.	Redlich-Kwong fluid, saturated relative heat capacities at constant pressure as a function of temperature	176
61.	Redlich-Kwong fluid, saturated relative heat capacities at constant pressure as a function of temperature near the critical point	177
62.	Redlich-Kwong fluid, asymptotic function of the saturated relative heat capacities at constant pressure as a function of temperature	180
63.	Redlich-Kwong fluid, differences in the saturated heat capacities at constant pressure as a function of temperature	184
64.	Redlich-Kwong fluid, differences in the saturated heat capacities at constant pressure as a function of temperature near the critical point	185
65.	Redlich-Kwong fluid, asymptotic function of the differences in the saturated heat capacities at constant pressure as a function of temperature . . .	188
66.	Redlich-Kwong fluid, heat of vaporization per mole of gas collected outside the calorimeter as a function of temperature	194
67.	Redlich-Kwong fluid, heat of vaporization per mole of gas collected outside the calorimeter as a function of temperature near the critical point	195

Page

68. Redlich-Kwong fluid, asymptotic function of the
heat of vaporization per mole of gas collected
outside the calorimeter as a function of
temperature 198
69. Redlich-Kwong fluid, second temperature derivative
of the vapor pressure curve as a function of
temperature 200
70. Redlich-Kwong fluid, second temperature derivative
of the vapor pressure curve as a function of
temperature near the critical point 201
71. Redlich-Kwong fluid, heat capacity of the saturated
gas as a function of temperature 205
72. Redlich-Kwong fluid, heat capacity of the saturated
gas as a function of temperature near the critical
point 206
73. Redlich-Kwong fluid, heat capacity of the saturated
liquid as a function of temperature 209
74. Redlich-Kwong fluid, heat capacity of the saturated
liquid as a function of temperature near the
critical point 210
75. Redlich-Kwong fluid, asymptotic function of the
heat capacities of the saturated liquid and
gas as a function of temperature 212
76. Redlich-Kwong fluid, second temperature derivative
of the chemical potential or Gibbs free energy,
at saturation, as a function of temperature 216
77. Redlich-Kwong fluid, second temperature derivative
of the chemical potential or Gibbs free energy,
at saturation, as a function of temperature near
the critical point 217
78. Redlich-Kwong fluid, heat capacity at constant
volume, with two phases present in the calorimeter
and the filling density equal to the critical
density, as a function of temperature 221

Page

79.	Redlich-Kwong fluid, heat capacity at constant volume, with two phases present in the calorimeter and the filling density equal to the critical density, as a function of temperature near the critical point	222
80.	Redlich-Kwong fluid, pressure-temperature coefficients at constant density, at saturation, as a function of temperature	225
81.	Redlich-Kwong fluid, pressure-temperature coefficients at constant density, at saturation, as a function of temperature near the critical point	226
82.	Redlich-Kwong fluid, asymptotic function of the pressure-temperature coefficients at constant density, at saturation, as a function of temperature . .	228
83.	Redlich-Kwong fluid, saturated pressure-density coefficients at constant temperature as a function of temperature	231
84.	Redlich-Kwong fluid, saturated pressure-density coefficients at constant temperature as a function of temperature near the critical point	232
85.	Redlich-Kwong fluid, saturated coefficients of compressibility at constant temperature as a function of temperature	235
86.	Redlich-Kwong fluid, saturated coefficients of compressibility at constant temperature as a function of temperature near the critical point	236
87.	Redlich-Kwong fluid, asymptotic function of the saturated coefficients of compressibility at constant temperature as a function of temperature . . .	238
88.	Redlich-Kwong fluid, differences in the saturated coefficients of compressibility at constant temperature as a function of temperature	242
89.	Redlich-Kwong fluid, differences in the saturated coefficients of compressibility at constant temperature as a function of temperature near the critical point	243

Page

90.	Redlich-Kwong fluid, asymptotic function of the differences in the saturated coefficients of compressibility at constant temperature as a function of temperature	246
91.	Redlich-Kwong fluid, logarithmic function of the saturated coefficients of compressibility at constant temperature as a function of the logarithm of the temperature	250
92.	Redlich-Kwong fluid, saturated coefficients of thermal expansion at constant pressure as a function of temperature	253
93.	Redlich-Kwong fluid, saturated coefficients of thermal expansion at constant pressure as a function of temperature near the critical point	254
94.	Redlich-Kwong fluid, asymptotic function of the saturated coefficients of thermal expansion at constant pressure as a function of temperature	256
95.	Redlich-Kwong fluid, differences in the saturated heat capacities at constant pressure and at constant volume as a function of temperature	260
96.	Redlich-Kwong fluid, differences in the saturated heat capacities at constant pressure and at constant volume as a function of temperature near the critical point	261
97.	Redlich-Kwong fluid, asymptotic function of the differences in the saturated heat capacities at constant pressure and at constant volume as a function of temperature	264
98.	Redlich-Kwong fluid, ratios of the saturated heat capacities at constant pressure and at constant volume as a function of temperature	267
99.	Redlich-Kwong fluid, ratios of the saturated heat capacities at constant pressure and at constant volume as a function of temperature near the critical point	268

Page

100.	Redlich-Kwong fluid, asymptotic function of the ratios of the saturated heat capacities at constant pressure and at constant volume as a function of temperature	271
101.	Redlich-Kwong fluid, saturated velocities of sound as a function of temperature	275
102.	Redlich-Kwong fluid, saturated velocities of sound as a function of temperature near the critical point	276
103.	Redlich-Kwong fluid, asymptotic function of the saturated velocities of sound as a function of temperature	278
104.	Redlich-Kwong fluid, saturated Joule-Thomson coefficients as a function of temperature	282
105.	Redlich-Kwong fluid, saturated Joule-Thomson coefficients as a function of temperature near the critical point	283
106.	Redlich-Kwong fluid, asymptotic function of the saturated Joule-Thomson coefficients as a function of temperature	285
107.	Redlich-Kwong fluid, Joule-Thomson inversion curve . . .	288
108.	Redlich-Kwong fluid, pressure as a function of density for the critical isotherm	290
109.	Redlich-Kwong fluid, compressibility factor as a function of density for the critical isotherm	293
110.	Redlich-Kwong fluid, log-log pressure-density data for the critical isotherm	295
111.	Redlich-Kwong fluid, velocity of sound as a function of density for the critical isotherm	298
112.	Redlich-Kwong fluid, discontinuities in the measured heat capacities at constant volume in passing from two phases present in the calorimeter to a single phase as a function of temperature	302

Page

113.	Redlich-Kwong fluid, discontinuities in the measured heat capacities at constant volume in passing from two phases present in the calorimeter to a single phase as a function of temperature near the critical point	303
114.	Redlich-Kwong fluid, asymptotic function of the discontinuities in the measured heat capacities at constant volume in passing from two phases present in the calorimeter to a single phase as a function of temperature	306

TABLES

1.	Redlich-Kwong fluid, saturated densities as a function of temperature	52
2.	Redlich-Kwong fluid, saturated volumes as a function of temperature	56
3.	Redlich-Kwong fluid, density-coexistence data as a function of temperature	59
4.	Redlich-Kwong fluid, volume-coexistence data as a function of temperature	63
5.	Redlich-Kwong fluid, coexistence data as a function of temperature	68
6.	Redlich-Kwong fluid, coexistence data as a function of pressure	74
7.	Redlich-Kwong fluid, vapor pressure data as a function of temperature	77
8.	Redlich-Kwong fluid, logarithm of the pressure as a function of reciprocal temperature	81
9.	Redlich-Kwong fluid, saturated compressibility factors as a function of temperature	84
10.	Redlich-Kwong fluid, asymptotic function of the saturated compressibility factors as a function of temperature	88

Page

11. Redlich-Kwong fluid, temperature coefficient of the
vapor pressure curve as a function of temperature 91
12. Redlich-Kwong fluid, logarithm of the temperature
coefficient of the vapor pressure curve as a
function of reciprocal temperature 94
13. Redlich-Kwong fluid, temperature coefficients of
the saturated liquid and gas densities as a
function of temperature 99
14. Redlich-Kwong fluid, asymptotic function of the
temperature coefficients of the saturated liquid
and gas densities as a function of temperature 104
15. Redlich-Kwong fluid, temperature coefficient of the
rectilinear diameter as a function of temperature 108
16. Redlich-Kwong fluid, logarithm of the fugacity
function, at saturation, as a function of
temperature 111
17. Redlich-Kwong fluid, logarithm of the fugacity
function, at saturation, as a function of
reciprocal temperature 115
18. Redlich-Kwong fluid, the fugacity function, at
saturation, as a function of the temperature 117
19. Redlich-Kwong fluid, relative Gibbs free energy,
at saturation, as a function of temperature 121
20. Redlich-Kwong fluid, saturated relative Helmholtz
free energies as a function of temperature 125
21. Redlich-Kwong fluid, asymptotic function of the
saturated relative Helmholtz free energies as
a function of temperature 128
22. Redlich-Kwong fluid, saturated relative entropies
as a function of temperature 131
23. Redlich-Kwong fluid, asymptotic function of the
saturated relative entropies as a function of
temperature 134

	<u>Page</u>
24. Redlich-Kwong fluid, entropy of vaporization as a function of temperature	137
25. Redlich-Kwong fluid, asymptotic function of the entropy of vaporization as a function of temperature . .	140
26. Redlich-Kwong fluid, saturated relative internal energies as a function of temperature	143
27. Redlich-Kwong fluid, asymptotic function of the saturated relative internal energies as a function of temperature	146
28. Redlich-Kwong fluid, saturated relative heat capacities at constant volume as a function of temperature	149
29. Redlich-Kwong fluid, asymptotic function of the saturated relative heat capacities at constant volume as a function of temperature	152
30. Redlich-Kwong fluid, differences in the saturated heat capacities at constant volume as a function of temperature	155
31. Redlich-Kwong fluid, asymptotic function of the differences in the saturated heat capacities at constant volume as a function of temperature	158
32. Redlich-Kwong fluid, saturated relative enthalpies as a function of temperature	161
33. Redlich-Kwong fluid, asymptotic function of the saturated relative enthalpies as a function of temperature	164
34. Redlich-Kwong fluid, heat of vaporization as a function of temperature	169
35. Redlich-Kwong fluid, asymptotic function of the heat of vaporization as a function of temperature	172
36. Redlich-Kwong fluid, saturated relative heat capacities at constant pressure as a function of temperature	175
37. Redlich-Kwong fluid, asymptotic function of the saturated relative heat capacities at constant pressure as a function of temperature	179

Page

38.	Redlich-Kwong fluid, differences in the saturated heat capacities at constant pressure as a function of temperature	183
39.	Redlich-Kwong fluid, asymptotic function of the differences in the saturated heat capacities at constant pressure as a function of temperature	186
40.	Redlich-Kwong fluid, heat of vaporization per mole of gas collected outside the calorimeter as a function of temperature	193
41.	Redlich-Kwong fluid, asymptotic function of the heat of vaporization per mole of gas collected outside the calorimeter as a function of temperature	196
42.	Redlich-Kwong fluid, second temperature derivative of the vapor pressure curve as a function of temperature	199
43.	Redlich-Kwong fluid, heat capacity of the saturated gas as a function of temperature	204
44.	Redlich-Kwong fluid, heat capacity of the saturated liquid as a function of temperature	207
45.	Redlich-Kwong fluid, asymptotic function of the heat capacities of the saturated liquid and gas as a function of temperature	211
46.	Redlich-Kwong fluid, second temperature derivative of the chemical potential or Gibbs free energy, at saturation, as a function of temperature	215
47.	Redlich-Kwong fluid, heat capacity at constant volume, with two phases present in the calorimeter and the filling density equal to the critical density, as a function of temperature	219
48.	Redlich-Kwong fluid, pressure-temperature coefficients at constant density, at saturation, as a function of temperature	224
49.	Redlich-Kwong fluid, asymptotic function of the pressure-temperature coefficients at constant density, at saturation, as a function of temperature	227

	<u>Page</u>
50. Redlich-Kwong fluid, saturated pressure-density coefficients at constant temperature as a function of temperature	230
51. Redlich-Kwong fluid, saturated coefficients of compressibility at constant temperature as a function of temperature	234
52. Redlich-Kwong fluid, asymptotic function of the saturated coefficients of compressibility at constant temperature as a function of temperature	237
53. Redlich-Kwong fluid, differences in the saturated coefficients of compressibility at constant temperature as a function of temperature	240
54. Redlich-Kwong fluid, asymptotic function of the differences in the saturated coefficients of compressibility at constant temperature as a function of temperature	245
55. Redlich-Kwong fluid, logarithmic function of the saturated coefficients of compressibility at constant temperature as a function of the logarithm of the temperature	249
56. Redlich-Kwong fluid, saturated coefficients of thermal expansion at constant pressure as a function of temperature	252
57. Redlich-Kwong fluid, asymptotic function of the saturated coefficients of thermal expansion at constant pressure as a function of temperature	255
58. Redlich-Kwong fluid, differences in the saturated heat capacities at constant pressure and at constant volume as a function of temperature	259
59. Redlich-Kwong fluid, asymptotic function of the differences in the saturated heat capacities at constant pressure and at constant volume as a function of temperature	262
60. Redlich-Kwong fluid, ratios of the saturated heat capacities at constant pressure and at constant volume as a function of temperature	266

Page

61. Redlich-Kwong fluid, asymptotic function of the ratios of the saturated heat capacities at constant pressure and at constant volume as a function of temperature	270
62. Redlich-Kwong fluid, saturated velocities of sound as a function of temperature	274
63. Redlich-Kwong fluid, asymptotic function of the saturated velocities of sound as a function of temperature	277
64. Redlich-Kwong fluid, saturated Joule-Thomson coefficients as a function of temperature	281
65. Redlich-Kwong fluid, asymptotic function of the saturated Joule-Thomson coefficients as a function of temperature	284
66. Redlich-Kwong fluid, Joule-Thomson inversion curve	287
67. Redlich-Kwong fluid, pressure as a function of density for the critical isotherm	289
68. Redlich-Kwong fluid, compressibility factor as a function of density for the critical isotherm	292
69. Redlich-Kwong fluid, log-log pressure-density data for the critical isotherm	294
70. Redlich-Kwong fluid, velocity of sound as a function of density for the critical isotherm	297
71. Redlich-Kwong fluid, discontinuities in the measured heat capacities at constant volume in passing from two phases present in the calorimeter to a single phase as a function of temperature	301
72. Redlich-Kwong fluid, asymptotic function of the discontinuities in the measured heat capacities at constant volume in passing from two phases present in the calorimeter to a single phase as a function of temperature	305

THERMODYNAMIC PROPERTIES OF A REDLICH-KWONG FLUID IN THE TWO-PHASE REGION

by

B. J. Dalton¹ and Robert E. Barieau²

ABSTRACT

The Bureau of Mines Helium Research Center has as a long-range objective the development of an equation of state for helium that will allow all of the thermodynamic properties to be calculated within the accuracy with which they are known. If this objective is to be realized, a method of calculation must be known. This report gives the principles of the method we use in such problems.

A computer program (8)³ was developed for predicting these properties, including those at the critical point, that is perfectly general and applicable to any equation of state. To demonstrate the efficacy of our method, this computer program was used to evaluate thermodynamic properties of a Redlich-Kwong fluid in the two-phase region. Expressions for calculating various thermodynamic functions specific for this particular equation of state are derived. Numerical values are tabulated and graphs are presented for all functions calculated.

¹Research chemist, Helium Research Center, Bureau of Mines, Amarillo, Tex.

²Supervisory research chemist, project leader, Thermodynamics, Helium Research Center, Bureau of Mines, Amarillo, Tex.

³Underlined numbers in parentheses refer to items in the list of references at the end of this report.

It is shown that for a Redlich-Kwong fluid there are finite discontinuities in (1) the second temperature derivative of the Gibbs free energy or chemical potential at the critical point, (2) the second derivative of the vapor pressure curve with regard to the temperature on passing through the critical point, and (3) the measured heat capacity at constant volume on passing through the critical temperature when the calorimeter is filled to the critical density. It is also shown that the heat of vaporization is infinite for a Redlich-Kwong fluid at absolute zero.

INTRODUCTION

This work is part of a broad program underway at the Helium Research Center for the development of a self-consistent, accurate equation of state for helium and helium mixtures from which all thermodynamic properties can be calculated within the accuracy with which they are known. This includes the calculation of all properties in the two-phase region. Accurate values of the thermodynamic properties of helium and helium mixtures are needed to design improved process and separation cycles for the extraction, concentration, and purification of helium. This information will contribute toward planning and coordinating efficient utilization of the nation's helium resources and for the future development of new uses for helium.

In a previous report (2), formulas were derived for calculating most of the thermodynamic properties of current interest from an empirical equation of state. From this report (2), a computer program

(8) was developed for predicting these properties, including those at the critical point. This computer program is perfectly general and is applicable to any equation of state. This computer program was used in the present work to evaluate various thermodynamic properties of a Redlich-Kwong fluid in the two-phase region.

The notation used for the thermodynamic functions is mainly that of Lewis and Randall (18), an exception being that G is used to represent the molal Gibbs free energy or chemical potential instead of F . The relative molal heat content is defined as Lewis and Randall originally defined this property. Relative molal properties have been extended to include heat capacity, internal energy, entropy, and free energy.

Numerical values are tabulated and illustrations are presented for all functions calculated. The numerical values listed in the tables are in "E format" (i.e., the number to the right of E indicates the exponent of 10 by which the number is to be multiplied). The numerical values listed within the tables and text have been truncated to the number of figures given.

Other than a previous Bureau publication (5) giving results for a van der Waals fluid, the authors are not aware of any previous publication in which these extensive calculations are presented.

ACKNOWLEDGMENT

The staff of the Helium Activity Branch of Automatic Data Processing wrote the computer program, carried out all calculations using

this program, and prepared the original illustrations using an automatic plotter. The staff of the Helium Activity Branch of Engineering Drafting prepared the illustrative material for publication. The authors thank the staffs of these two groups for this valuable aid.

MATHEMATICAL NOMENCLATURE AND SYMBOLISM

In this report, all molal thermodynamic functions are assumed to be explicit functions of the molal density, ρ , and the absolute thermodynamic temperature, T :

$$W = W(\rho, T) \quad , \quad (1)$$

where W is any molal thermodynamic property of a homogeneous phase. Then for a differential change, we have

$$dW = \left(\frac{\partial W}{\partial \rho} \right)_T d\rho + \left(\frac{\partial W}{\partial T} \right)_\rho dT \quad . \quad (2)$$

For all partial derivatives involving the variables ρ and T , we will use a subscript. Thus, we write

$$W_\rho = \left(\frac{\partial W}{\partial \rho} \right)_T \quad , \quad (3)$$

$$W_T = \left(\frac{\partial W}{\partial T} \right)_\rho \quad . \quad (4)$$

We extend this symbolism to second derivatives by writing

$$W_{\rho\rho} = \left(\frac{\partial W_\rho}{\partial \rho} \right)_T = \left(\frac{\partial^2 W}{\partial \rho^2} \right)_T \quad , \quad (5)$$

$$W_{\rho T} = \left(\frac{\partial W_\rho}{\partial T} \right)_\rho = \left(\frac{\partial W_T}{\partial \rho} \right)_T \quad , \quad (6)$$

$$W_{TT} = \left(\frac{\partial W_T}{\partial T} \right)_\rho = \left(\frac{\partial^2 W}{\partial T^2} \right)_\rho \quad . \quad (7)$$

The extension of this symbolism to higher order derivatives involving the variables ρ and T should be obvious.

Thus, consistent with our symbolism, we write equation 2 as

$$dW = W_\rho d\rho + W_T dT \quad . \quad (8)$$

If we wish to express the change in W with temperature, keeping the pressure, P , constant, we have

$$\left(\frac{\partial W}{\partial T}\right)_P = W_T + W_\rho \left(\frac{\partial \rho}{\partial T}\right)_P \quad . \quad (9)$$

For partial derivatives involving variables other than ρ and T , we will use a small curly d , ∂ , to indicate a differential as in the left-hand side of equation 9.

Higher order derivatives involving variables other than ρ and T are obtained as follows. Differentiating equation 9 with regard to T , keeping P constant, we have

$$\left(\frac{\partial^2 W}{\partial T^2}\right)_P = \left(\frac{\partial W_T}{\partial T}\right)_P + \left(\frac{\partial W_\rho}{\partial T}\right)_P \left(\frac{\partial \rho}{\partial T}\right)_P + W_\rho \left(\frac{\partial^2 \rho}{\partial T^2}\right)_P \quad . \quad (10)$$

But

$$\left(\frac{\partial W_T}{\partial T}\right)_P = W_{TT} + W_{\rho T} \left(\frac{\partial \rho}{\partial T}\right)_P \quad (11)$$

and

$$\left(\frac{\partial W_\rho}{\partial T}\right)_P = W_{\rho T} + W_{\rho\rho} \left(\frac{\partial \rho}{\partial T}\right)_P \quad . \quad (12)$$

Substituting equations 11 and 12 in equation 10, we find that

$$\left(\frac{\partial^2 W}{\partial T^2}\right)_P = W_{TT} + 2W_{\rho T} \left(\frac{\partial \rho}{\partial T}\right)_P + W_{\rho\rho} \left(\frac{\partial \rho}{\partial T}\right)_P^2 + W_\rho \left(\frac{\partial^2 \rho}{\partial T^2}\right)_P \quad . \quad (13)$$

If we have two phases in equilibrium and we wish to express the change of W with temperature, but maintaining the two phases in equilibrium, we write

$$\begin{aligned}\frac{dW}{dT} &= \left(\frac{\partial W}{\partial \rho}\right)_T \frac{d\rho}{dT} + \left(\frac{\partial W}{\partial T}\right)_\rho, \\ &= W_\rho \frac{d\rho}{dT} + W_T\end{aligned}\quad (14)$$

and in this type of derivative, we use a small d to indicate a differential (when two phases remain in equilibrium) as in the left-hand side of equation 14.

THE REDLICH-KWONG EQUATION OF STATE

The Redlich-Kwong equation of state (21) is

$$P = \frac{RT\rho}{(1-b'\rho)} - \frac{a'\rho^2}{(1+b'\rho)T^{1/2}}, \quad (15)$$

where R is the gas constant and a' and b' are constants. In terms of the compressibility factor, equation 15 may be written as

$$Z = \frac{P}{\rho RT} = \frac{1}{(1-b'\rho)} - \frac{a'\rho}{RT^{3/2}(1+b'\rho)}, \quad (16)$$

where Z is the compressibility factor and is defined by equation 16.

We define

$$\alpha = \rho/\rho_c, \text{ the reduced molal density,} \quad (17)$$

$$\beta = P/P_c, \text{ the reduced pressure, and} \quad (18)$$

$$\gamma = T/T_c, \text{ the reduced absolute thermodynamic temperature,} \quad (19)$$

where ρ_c , P_c , and T_c represent molal density, pressure, and temperature at the critical point.

Substituting equations 17 and 19 in equation 16,

$$Z = \frac{1}{(1-b'\rho_c\alpha)} - \frac{(a'\rho_c/RT_c^{3/2})\alpha}{\gamma^{3/2}(1+b'\rho_c\alpha)}. \quad (20)$$

The two constants of the Redlich-Kwong equation of state may be determined from the critical conditions (2). The results are:

$$a = (a' \rho_c / RT_c^{3/2}) = [3(2^{1/3} - 1)]^{-1} = 1.28244 \quad , \quad (21)$$

$$b = b' \rho_c = (2^{1/3} - 1) = 0.259921 \quad , \quad (22)$$

$$Z_c = 1/3 \quad , \quad (23)$$

where Z_c is the compressibility factor at the critical point.

Substituting equations 21 and 22 in equation 20,

$$Z = \frac{1}{(1-b\alpha)} - \frac{a\alpha}{\gamma^{3/2}(1+b\alpha)} \quad . \quad (24)$$

Equation 24 is the expression for the compressibility factor of a Redlich-Kwong fluid in terms of the reduced variables of density and temperature.

The reduced pressure is given by

$$\begin{aligned} \beta &= (P/P_c) = (\rho/\rho_c)(T/T_c)(Z/Z_c) \quad , \\ &= \frac{\alpha\gamma Z}{Z_c} \end{aligned} \quad (25)$$

or, with equations 23 and 24,

$$\beta = 3\alpha\gamma \left[\frac{1}{(1-b\alpha)} - \frac{a\alpha}{\gamma^{3/2}(1+b\alpha)} \right] \quad , \quad (26)$$

which is the expression for the reduced pressure of a Redlich-Kwong fluid in terms of the reduced variables of density and temperature.

To calculate all of the thermodynamic properties of a pure material, including those in the two-phase region, from a single equation of state, various partial derivatives of the pressure or of the compressibility factor must be evaluated along with the value of the integral

$$X = \int_0^{\alpha} (Z-1) \frac{d\alpha}{\alpha} . \quad (27)$$

In addition, various partial derivatives of the above integral must be calculated. Since all functions can be differentiated, if X can be expressed analytically, then all thermodynamic functions can be expressed analytically as explicit functions of the reduced variables of density and temperature.

For a Redlich-Kwong fluid, the integral X as defined above is integrable and differentiable with respect to the reduced variables of density and temperature and can be expressed analytically in terms of these same variables. We show in this report that if the quantities given by equations 28-38 have been calculated, then all thermodynamic properties, including those at the critical, can be determined:

$$Z_{\alpha} = \left(\frac{\partial Z}{\partial \alpha} \right)_{\gamma} = \frac{b}{(1-b\alpha)^2} - \frac{a}{\gamma^{3/2} (1+b\alpha)^2} ; \quad (28)$$

$$Z_{\gamma} = \left(\frac{\partial Z}{\partial \gamma} \right)_{\alpha} = \frac{3a\alpha}{2\gamma^{5/2} (1+b\alpha)} ; \quad (29)$$

$$Z_{\alpha\alpha} = \left(\frac{\partial Z_{\alpha}}{\partial \alpha} \right)_{\gamma} = 2b \left[\frac{b}{(1-b\alpha)^3} + \frac{a}{\gamma^{3/2} (1+b\alpha)^3} \right] ; \quad (30)$$

$$Z_{\alpha\gamma} = \left(\frac{\partial Z_{\alpha}}{\partial \gamma} \right)_{\alpha} = \left(\frac{\partial Z_{\gamma}}{\partial \alpha} \right)_{\gamma} = \frac{3a}{2\gamma^{5/2} (1+b\alpha)^2} ; \quad (31)$$

$$Z_{\gamma\gamma} = \left(\frac{\partial Z_{\gamma}}{\partial \gamma} \right)_{\alpha} = - \frac{15a\alpha}{4\gamma^{7/2} (1+b\alpha)} ; \quad (32)$$

$$Z_{\alpha\alpha\alpha} = \left(\frac{\partial Z}{\partial \alpha} \right)_\gamma = 6b^2 \left[\frac{b}{(1-b\alpha)^4} - \frac{a}{\gamma^{3/2} (1+b\alpha)^4} \right] ; \quad (33)$$

$$Z_{\alpha\alpha\gamma} = \left(\frac{\partial Z}{\partial \alpha} \right)_\gamma = \left(\frac{\partial Z}{\partial \gamma} \right)_\alpha = - \frac{3ab}{\gamma^{5/2} (1+b\alpha)^3} ; \quad (34)$$

$$Z_{\alpha\alpha\alpha\alpha} = \left(\frac{\partial Z}{\partial \alpha} \right)_\gamma = 24b^3 \left[\frac{b}{(1-b\alpha)^5} + \frac{a}{\gamma^{3/2} (1+b\alpha)^5} \right] ; \quad (35)$$

$$X = \int_0^\alpha (Z-1) \frac{d\alpha}{\alpha} = -\ln(1-b\alpha) - \frac{a}{b\gamma^{3/2}} \ln(1+b\alpha) ; \quad (36)$$

$$X_\gamma = \int_0^\alpha Z_\gamma \frac{d\alpha}{\alpha} = \left(\frac{\partial X}{\partial \gamma} \right)_\alpha = \frac{3a}{2b\gamma^{5/2}} \ln(1+b\alpha) ; \quad (37)$$

$$X_{\gamma\gamma} = \int_0^\alpha Z_{\gamma\gamma} \frac{d\alpha}{\alpha} = \left(\frac{\partial X_\gamma}{\partial \gamma} \right)_\alpha = - \frac{15a}{4b\gamma^{7/2}} \ln(1+b\alpha) . \quad (38)$$

At the critical point, where $\alpha=1$, $\beta=1$, $\gamma=1$:

$$(Z_\alpha)_{c.p.} = -Z_c = -1/3 ; \quad (39)$$

$$(Z_\gamma)_{c.p.} = 1.52681 ; \quad (40)$$

$$(Z_{\alpha\alpha})_{c.p.} = 2Z_c = 2/3 ; \quad (41)$$

$$(Z_{\alpha\gamma})_{c.p.} = 1.21183 ; \quad (42)$$

$$(Z_{\gamma\gamma})_{c.p.} = -3.81702 ; \quad (43)$$

$$(Z_{\alpha\alpha\alpha})_{c.p.} = 0.144907 ; \quad (44)$$

$$(Z_{\alpha\alpha\gamma})_{c.p.} = -1/2 ; \quad (45)$$

$$(Z_{\alpha\alpha\alpha})_{c.p.} = 0.663623 ; \quad (46)$$

$$(X)_{c.p.} = -0.838988 ; \quad (47)$$

$$(X_Y)_{c.p.} = 1.70998 ; \quad (48)$$

$$(X_{YY})_{c.p.} = -4.27495 . \quad (49)$$

THE PRESSURE-TEMPERATURE COEFFICIENT AT CONSTANT DENSITY

From equations 25 and 26, we find that

$$\beta_Y = \left(\frac{\partial \beta}{\partial Y} \right)_\alpha = \frac{\alpha}{Z_c} [Z + \gamma Z_Y] = 3\alpha \left[\frac{1}{(1-b\alpha)} + \frac{a\alpha}{2\gamma^{3/2}(1+b\alpha)} \right] . \quad (50)$$

At the critical point,

$$(\beta_Y)_{c.p.} = 1 + \frac{(Z_Y)_{c.p.}}{Z_c} = 5.58043 . \quad (51)$$

THE PRESSURE-DENSITY COEFFICIENT AT CONSTANT TEMPERATURE

From equations 25 and 26, we have

$$\beta_\alpha = \left(\frac{\partial \beta}{\partial \alpha} \right)_Y = \frac{Y}{Z_c} [Z + \alpha Z_\alpha] = 3Y \left[\frac{1}{(1-b\alpha)^2} - \frac{a\alpha(2+b\alpha)}{\gamma^{3/2}(1+b\alpha)^2} \right] . \quad (52)$$

At the critical point,

$$(\beta_\alpha)_{c.p.} = 0 . \quad (53)$$

THE DENSITY-TEMPERATURE COEFFICIENT AT CONSTANT PRESSURE

The density-temperature coefficient at constant pressure may be expressed as

$$\left(\frac{\partial \alpha}{\partial Y} \right)_\beta = - \frac{(\partial \beta / \partial Y)_\alpha}{(\partial \beta / \partial \alpha)_Y} = - \frac{\beta_Y}{\beta_\alpha} . \quad (54)$$

Substituting equations 50 and 52 in equation 54,

$$\left(\frac{\partial \alpha}{\partial \gamma}\right)_{\beta} = - \frac{\alpha[Z + \gamma Z_{\gamma}]}{\gamma[Z + \alpha Z_{\alpha}]} = - \frac{\alpha(1-b\alpha)(1+b\alpha)[\gamma^{3/2}(1+b\alpha) + (a\alpha/2)(1-b\alpha)]}{\gamma[\gamma^{3/2}(1+b\alpha)^2 - a\alpha(1-b\alpha)^2(2+b\alpha)]} \quad (55)$$

At the critical point,

$$\left[\left(\frac{\partial \alpha}{\partial \gamma}\right)_{\beta}\right]_{c.p.} = \pm \infty, \quad (56)$$

where the limiting value of this function depends on the path chosen in approaching the critical point. Obviously, there is only one limiting value when the critical point is approached from physically realizable states. This statement applies to other functions in this report which we indicate are multivalued at the critical point.

THE SECOND DERIVATIVE OF THE PRESSURE WITH REGARD TO THE TEMPERATURE AT CONSTANT DENSITY

Differentiating equation 50,

$$\beta_{\gamma\gamma} = \left(\frac{\partial \beta_{\gamma}}{\partial \gamma}\right)_{\alpha} = \frac{\alpha}{Z_c} [2Z_{\gamma} + \gamma Z_{\gamma\gamma}] = - \frac{9a\alpha^2}{4\gamma^{5/2}(1+b\alpha)} \quad (57)$$

At the critical point,

$$(\beta_{\gamma\gamma})_{c.p.} = \frac{[2Z_{\gamma} + \gamma Z_{\gamma\gamma}]_{c.p.}}{Z_c} = -2.29021 \quad (58)$$

THE COEFFICIENT OF COMPRESSIBILITY AT CONSTANT TEMPERATURE

In a previous Bureau report (5), it is shown that the reduced coefficient of compressibility at constant temperature is expressible as

$$- \frac{P_c}{V} \left(\frac{\partial V}{\partial P}\right)_T = \frac{1}{\alpha} \left(\frac{\partial \alpha}{\partial \beta}\right)_{\gamma} = \frac{1}{\alpha \beta_{\alpha}}, \quad (59)$$

where V is the molal volume. Substituting equation 52 in equation 59,

$$\frac{1}{\alpha} \left(\frac{\partial \alpha}{\partial \beta} \right)_\gamma = \frac{Z_c}{\alpha \gamma [Z + \alpha Z_\alpha]} = \frac{\gamma^{1/2} (1 - b\alpha)^2 (1 + b\alpha)^2}{3\alpha [\gamma^{3/2} (1 + b\alpha)^2 - a\alpha (1 - b\alpha)^2 (2 + b\alpha)]} \quad (60)$$

At the critical point,

$$\left[\frac{1}{\alpha} \left(\frac{\partial \alpha}{\partial \beta} \right)_\gamma \right]_{c.p.} = \pm \infty \quad (61)$$

THE COEFFICIENT OF THERMAL EXPANSION AT CONSTANT PRESSURE

The reduced coefficient of thermal expansion at constant pressure in terms of the reduced variables of density and temperature is given by (5)

$$\frac{T_c}{V} \left(\frac{\partial V}{\partial T} \right)_p = - \frac{1}{\alpha} \left(\frac{\partial \alpha}{\partial \gamma} \right)_\beta \quad (62)$$

Substituting equation 55 in equation 62,

$$- \frac{1}{\alpha} \left(\frac{\partial \alpha}{\partial \gamma} \right)_\beta = \frac{[Z + \gamma Z_\gamma]}{\gamma [Z + \alpha Z_\alpha]} = \frac{(1 - b\alpha)(1 + b\alpha) [\gamma^{3/2} (1 + b\alpha) + (a\alpha/2)(1 - b\alpha)]}{\gamma [\gamma^{3/2} (1 + b\alpha)^2 - a\alpha (1 - b\alpha)^2 (2 + b\alpha)]} \quad (63)$$

At the critical point,

$$\left[- \frac{1}{\alpha} \left(\frac{\partial \alpha}{\partial \gamma} \right)_\beta \right]_{c.p.} = \pm \infty \quad (64)$$

PARTIAL DERIVATIVES OF X WHICH CAN BE CALCULATED FROM PREVIOUSLY CALCULATED QUANTITIES

The following partial derivatives of X , which will be used later in this report, can be calculated from previously calculated quantities:

$$X_{\alpha} = \left(\frac{\partial X}{\partial \alpha} \right)_{\gamma} = \frac{Z-1}{\alpha} = \left[\frac{b}{(1-b\alpha)} - \frac{a}{\gamma^{3/2}(1+b\alpha)} \right] ; \quad (65)$$

$$X_{\alpha\alpha} = \left(\frac{\partial X_{\alpha}}{\partial \alpha} \right)_{\gamma} = \frac{\alpha Z_{\alpha} - (Z-1)}{\alpha^2} = b \left[\frac{b}{(1-b\alpha)^2} + \frac{a}{\gamma^{3/2}(1+b\alpha)^2} \right] ; \quad (66)$$

$$X_{\alpha\gamma} = \left(\frac{\partial X_{\alpha}}{\partial \gamma} \right)_{\alpha} = \left(\frac{\partial X_{\gamma}}{\partial \alpha} \right)_{\gamma} = \frac{Z_{\gamma}}{\alpha} = \frac{3a}{2\gamma^{5/2}(1+b\alpha)} . \quad (67)$$

THE FUGACITY FUNCTION

In a previous report (2), it is shown that

$$\ln \frac{f}{P} = (Z-1) - \ln Z + X , \quad (68)$$

where f is the fugacity. Substituting equations 24 and 36 in equation 68,

$$\begin{aligned} \ln \frac{f}{P} &= \alpha \left[\frac{b}{(1-b\alpha)} - \frac{a}{\gamma^{3/2}(1+b\alpha)} \right] + \left[1 - \frac{a}{b\gamma^{3/2}} \right] \ln(1+b\alpha) \\ &\quad - \ln \left[(1+b\alpha) - \frac{a\alpha(1-b\alpha)}{\gamma^{3/2}} \right] . \end{aligned} \quad (69)$$

At the critical point,

$$\ln \frac{f_c}{P_c} = \left[Z_c - 1 - \ln Z_c + (X)_c . p . \right] = -0.407043 . \quad (70)$$

Taking the antilogarithm,

$$\frac{f_c}{P_c} = 0.665615 . \quad (71)$$

THE RELATIVE GIBBS FREE ENERGY

From the definition of fugacity (18),

$$(G-G^0) = RT \ln f , \quad (72)$$

where $(G-G^0)$ is the relative molal Gibbs free energy. In terms of the reduced variables of density and temperature, the relative Gibbs free energy is expressible as

$$\frac{(G-G^0) - RT \ln P_c}{RT_c} = \gamma \left[\ln \frac{\alpha Y}{Z_c} + (Z-1) + X \right] \quad (73)$$

Substituting equations 23, 24, and 36 in equation 73,

$$\frac{(G-G^0) - RT \ln P_c}{RT_c} = \gamma \left[\ln \frac{3\alpha Y}{(1-b\alpha)} + \frac{b\alpha}{(1-b\alpha)} - \frac{a\alpha}{\gamma^{3/2}(1+b\alpha)} - \frac{a}{b\gamma^{3/2}} \ln(1+b\alpha) \right] \quad (74)$$

At the critical point,

$$\frac{(G_c - G_c^0) - RT_c \ln P_c}{RT_c} = [-\ln Z_c + Z_c - 1 + (X)_{c.p.}] = -0.407043 \quad (75)$$

THE RELATIVE HELMHOLTZ FREE ENERGY

From thermodynamics (18),

$$(A-A^0) = (G-G^0) - RT (Z-1) \quad (76)$$

where $(A-A^0)$ is the relative molal Helmholtz free energy. Substituting equations 68 and 72 in equation 76,

$$\begin{aligned} (A-A^0) &= RT \left[\ln \frac{P}{Z} + X \right] \\ &= RT [\ln \rho RT + X] \end{aligned} \quad (77)$$

In terms of the reduced variables of density and temperature, the relative Helmholtz free energy is expressible as

$$\frac{(A-A^0) - RT \ln P_c}{RT_c} = \gamma \left[\ln \frac{\alpha Y}{Z_c} + X \right] \quad (78)$$

Substituting equations 23 and 36 in equation 78,

$$\frac{(A-A^{\circ})}{RT_c} - \ln P_c = \gamma \left[\ln \frac{3\alpha\gamma}{(1-b\alpha)} - \frac{a}{b\gamma^{3/2}} \ln(1+b\alpha) \right] . \quad (79)$$

At the critical point,

$$\frac{(A_c - A_c^{\circ})}{RT_c} - \ln P_c = \left[-\ln Z_c + (X)_c . p . \right] = 0.259623 . \quad (80)$$

THE RELATIVE ENTROPY

In a previous report (2), it is shown that

$$\frac{(S-S^{\circ})}{R} + \ln P_c = - \left[\ln \frac{\alpha\gamma}{Z_c} + X + \gamma X_{\gamma} \right] , \quad (81)$$

where S is the molal entropy at α and γ , S° is the molal entropy of the hypothetical fluid in the ideal state at unit pressure, and $(S-S^{\circ})$ is the relative molal entropy.

Substituting equations 23, 36, and 37 in equation 81,

$$\frac{(S-S^{\circ})}{R} + \ln P_c = - \left[\ln \frac{3\alpha\gamma}{(1-b\alpha)} + \frac{a}{2b\gamma^{3/2}} \ln(1+b\alpha) \right] . \quad (82)$$

At the critical point,

$$\frac{(S_c - S_c^{\circ})}{R} + \ln P_c = \left[\ln Z_c - (X+X_{\gamma})_c . p . \right] = -1.96960 . \quad (83)$$

THE RELATIVE INTERNAL ENERGY

In a previous Bureau report (2), it is shown that

$$\frac{(E-E^{\circ})}{RT_c} = -\gamma^2 X_{\gamma} , \quad (84)$$

where E is the molal internal energy at α and γ , E° is the molal internal energy at zero density at the same temperature γ , and $(E-E^{\circ})$ is the relative molal internal energy.

Substituting equation 37 in equation 84,

$$\frac{(E-E^0)}{RT_c} = - \frac{3a}{2b\gamma^{1/2}} \ln(1+b\alpha) \quad (85)$$

At the critical point,

$$\frac{(E_c-E_c^0)}{RT_c} = - (X_Y)_{c.p.} = -1.70998 \quad (86)$$

THE RELATIVE HEAT CAPACITY AT CONSTANT VOLUME

In a previous report (2), we find

$$\frac{(C_V - C_V^0)}{R} = -\gamma(2X_Y + \gamma X_{YY}) \quad (87)$$

where C_V is the molal heat capacity at constant volume at α and γ , C_V^0 is the molal heat capacity at constant volume at zero pressure or density, and $(C_V - C_V^0)$ is the relative molal heat capacity at constant volume.

Substituting equations 37 and 38 in equation 87,

$$\frac{(C_V - C_V^0)}{R} = \frac{3a}{4b\gamma^{3/2}} \ln(1+b\alpha) \quad (88)$$

At the critical point,

$$\left[\frac{C_V - C_V^0}{R} \right]_{c.p.} = -(2X_Y + X_{YY})_{c.p.} = 0.854990 \quad (89)$$

THE RELATIVE HEAT CONTENT OR THE RELATIVE ENTHALPY

It has been shown in a previous report (2) that

$$\frac{L}{RT_c} = \frac{(H-H^0)}{RT_c} = \gamma[(Z-1) - \gamma X_Y] \quad (90)$$

where H is the molal enthalpy at α and γ , H^0 is the molal enthalpy

at zero pressure at temperature γ , and $L = (H-H^0)$ is the relative molal enthalpy or the relative molal heat content.

Substituting equations 24 and 37 in equation 90,

$$\frac{L}{RT_c} = \frac{b\alpha\gamma}{(1-b\alpha)} - \frac{a[2b\alpha + 3(1+b\alpha) \ln(1+b\alpha)]}{2b\gamma^{1/2}(1+b\alpha)} \quad (91)$$

At the critical point,

$$\frac{L_c}{RT_c} = [Z_c - 1 - (X_\gamma)_c] = -2.37664 \quad (92)$$

THE RELATIVE HEAT CAPACITY AT CONSTANT PRESSURE

In a previous report (2), it is shown that

$$\begin{aligned} \frac{J}{R} &= \frac{(C_p - C_p^0)}{R} = \frac{1}{RT_c} \left[L_\gamma + L_\alpha (\partial\alpha/\partial\gamma)_\beta \right] , \\ &= \frac{1}{RT_c} \left[L_\gamma - L_\alpha \frac{\beta_\gamma}{\beta_\alpha} \right] , \end{aligned} \quad (93)$$

where C_p is the molal heat capacity at constant pressure at α and γ , C_p^0 is the corresponding quantity at the same temperature γ but for $\alpha=0$, and $J = (C_p - C_p^0)$ is the relative molal heat capacity at constant pressure.

From equation 90, one may obtain

$$\frac{L_\gamma}{RT_c} = \frac{1}{RT_c} \left(\frac{\partial L}{\partial \gamma} \right)_\alpha = (Z-1) + \gamma Z_\gamma - \gamma(2X_\gamma + \gamma X_{\gamma\gamma}) \quad (94)$$

or, substituting equation 87 in equation 94,

$$\frac{L_\gamma}{RT_c} = \frac{(C_v - C_v^0)}{R} + (Z-1) + \gamma Z_\gamma \quad (95)$$

Also, from equation 90 we find that

$$\frac{L_\alpha}{RT_c} = \frac{1}{RT_c} \left(\frac{\partial L}{\partial \alpha} \right)_\gamma = \gamma (Z_\alpha - \gamma X_{\alpha\gamma}) \quad (96)$$

or, substituting equation 67 in equation 96,

$$\frac{L_\alpha}{RT_c} = \frac{\gamma}{\alpha} [\alpha Z_\alpha - \gamma Z_\gamma] \quad (97)$$

Substituting equations 95 and 97 in equation 93,

$$\frac{J}{R} = \frac{(C_P - C_P^0)}{R} = \frac{(C_V - C_V^0)}{R} - 1 + (Z + \gamma Z_\gamma) - \frac{\gamma \beta_\gamma}{\alpha \beta_\alpha} (\alpha Z_\alpha - \gamma Z_\gamma) \quad (98)$$

But from equation 50, we find that

$$Z + \gamma Z_\gamma = \frac{Z_c \beta_\gamma}{\alpha} \quad (99)$$

From equation 52, we find that

$$\alpha Z_\alpha = \frac{Z_c \beta_\alpha}{\gamma} - Z \quad (100)$$

From equation 99, it follows that

$$-\gamma Z_\gamma = Z - \frac{Z_c \beta_\gamma}{\alpha} \quad (101)$$

Adding equations 100 and 101,

$$(\alpha Z_\alpha - \gamma Z_\gamma) = \frac{Z_c}{\alpha \gamma} (\alpha \beta_\alpha - \gamma \beta_\gamma) \quad (102)$$

Substituting equations 99 and 102 in equation 98,

$$\begin{aligned} \frac{J}{R} &= \frac{(C_P - C_P^0)}{R} = \frac{(C_V - C_V^0)}{R} - 1 + \frac{Z_c \beta_\gamma}{\alpha} \left\{ 1 - \frac{(\alpha \beta_\alpha - \gamma \beta_\gamma)}{\alpha \beta_\alpha} \right\} \\ &= \frac{(C_V - C_V^0)}{R} - 1 + \frac{\gamma Z_c \beta_\gamma^2}{\alpha^2 \beta_\alpha} \end{aligned} \quad (103)$$

Substituting equations 23, 50, 52, and 88 in equation 103,

$$\frac{J}{R} = \frac{3a}{4b\gamma^{3/2}} \ln(1+b\alpha) - 1 + \frac{[\gamma^{3/2}(1+b\alpha) + (a\alpha/2)(1-b\alpha)]^2}{\gamma^{3/2}[\gamma^{3/2}(1+b\alpha)^2 - a\alpha(1-b\alpha)^2(2+b\alpha)]} \quad (104)$$

At the critical point,

$$\left(\frac{J}{R}\right)_{c.p.} = \left[\frac{C_V - C_V^0}{R}\right]_{c.p.} + \frac{Z_c (\beta_Y)_{c.p.}^2}{(\beta_\alpha)_{c.p.}} - 1 = \pm \infty \quad (105)$$

THE SECOND DERIVATIVE OF THE CHEMICAL POTENTIAL OR GIBBS FREE ENERGY WITH REGARD TO THE TEMPERATURE AT CONSTANT DENSITY

In a previous report (2), we find that

$$\frac{T\left(\frac{\partial^2 G}{\partial T^2}\right)_\rho + C_V^0}{R} = \gamma(2X_Y + \gamma X_{YY}) + \gamma(2Z_Y + \gamma Z_{YY}) \quad (106)$$

From equation 57, it follows that

$$(2Z_Y + \gamma Z_{YY}) = \frac{Z_c}{\alpha} \beta_{YY} \quad (107)$$

Substituting equation 107 in equation 106,

$$\frac{T\left(\frac{\partial^2 G}{\partial T^2}\right)_\rho + C_V^0}{R} = \gamma(2X_Y + \gamma X_{YY}) + \frac{Z_c \gamma}{\alpha} \beta_{YY} \quad (108)$$

Substituting equations 23, 37, 38, and 57 in equation 108,

$$\frac{T\left(\frac{\partial^2 G}{\partial T^2}\right)_\rho + C_V^0}{R} = -\frac{3a}{4\gamma^{3/2}} \left[\frac{\alpha}{(1+b\alpha)} + \frac{1}{b} \ln(1+b\alpha) \right] \quad (109)$$

At the critical point, from equation 108

$$\left[\frac{T\left(\frac{\partial^2 G}{\partial T^2}\right)_\rho + C_V^0}{R} \right]_{c.p.} = \left[2(X_Y)_{c.p.} + (X_{YY})_{c.p.} + Z_c (\beta_{YY})_{c.p.} \right] = -1.61839 \quad (110)$$

THE DIFFERENCE BETWEEN THE HEAT CAPACITIES AT CONSTANT
PRESSURE AND AT CONSTANT VOLUME

In a previous report (2), we find

$$\frac{C_p - C_v}{R} = \frac{(Z + \gamma Z_\gamma)^2}{(Z + \alpha Z_\alpha)} \quad (111)$$

From equation 52, we find that

$$(Z + \alpha Z_\alpha) = \frac{Z_c \beta_\alpha}{\gamma} \quad (112)$$

Substituting equations 99 and 112 in equation 111,

$$\frac{C_p - C_v}{R} = \frac{Z_c^2 \beta_\gamma^2 \gamma}{\alpha^2 Z_c \beta_\alpha} = \frac{\gamma Z_c \beta_\gamma^2}{\alpha^2 \beta_\alpha} \quad (113)$$

Substituting equations 23, 50, and 52 in equation 113,

$$\frac{C_p - C_v}{R} = \frac{[\gamma^{3/2} (1+b\alpha) + (a\alpha/2)(1-b\alpha)]^2}{\gamma^{3/2} [\gamma^{3/2} (1+b\alpha)^2 - a\alpha(1-b\alpha)^2 (2+b\alpha)]} \quad (114)$$

At the critical point,

$$\left[\frac{C_p - C_v}{R} \right]_{c.p.} = \frac{Z_c (\beta_\gamma)_c^2 . p.}{(\beta_\alpha)_c . p.} = \pm \infty \quad (115)$$

THE RATIO OF THE HEAT CAPACITIES AT CONSTANT
PRESSURE AND AT CONSTANT VOLUME

Multiplying equation 113 by R/C_v ,

$$\frac{C_p}{C_v} - 1 = \frac{\gamma Z_c \beta_\gamma^2}{\alpha^2 \beta_\alpha (C_v/R)} \quad (116)$$

which, from equations 88, 113, and 114, can be written as

$$\frac{C_p}{C_v} = 1 + \frac{[\gamma^{3/2} (1+b\alpha) + (a\alpha/2)(1-b\alpha)]^2}{\gamma^{3/2} [\gamma^{3/2} (1+b\alpha)^2 - a\alpha(1-b\alpha)^2 (2+b\alpha)] \left[\frac{C_v^0}{R} + \frac{3a}{4b\gamma^{3/2}} \ln(1+b\alpha) \right]} \quad (117)$$

At the critical point,

$$\left(\frac{C_p}{C_v}\right)_{c.p.} = \frac{Z_c (\beta_\gamma)_{c.p.}^2}{[\beta_\alpha (C_v/R)]_{c.p.}} = \pm \infty \quad (118)$$

THE VELOCITY OF SOUND

In a previous Bureau report (5), it is shown that

$$\frac{Ma^2}{RT_c} = \frac{C_p}{C_v} Z_c \beta_\alpha \quad (119)$$

where M is the molecular weight and α is the velocity of sound.

Substituting equation 116 in equation 119,

$$\frac{Ma^2}{RT_c} = Z_c \beta_\alpha + \frac{\gamma Z_c^2 \beta_\gamma^2}{\alpha^2 (C_v/R)} \quad (120)$$

Substituting equations 23, 50, 52, and 88 in equation 120,

$$\begin{aligned} \frac{Ma^2}{RT_c} = & \frac{[\gamma^{3/2} (1+b\alpha)^2 - a\alpha (1-b\alpha)^2 (2+b\alpha)]}{\gamma^{1/2} (1-b\alpha)^2 (1+b\alpha)^2} \\ & + \frac{[\gamma^{3/2} (1+b\alpha) + (a\alpha/2) (1-b\alpha)]^2}{\gamma^2 (1-b\alpha)^2 (1+b\alpha)^2 \left[\frac{C_v^0}{R} + \frac{3a}{4b\gamma^{3/2}} \ln(1+b\alpha) \right]} \quad (121) \end{aligned}$$

At the critical point,

$$\frac{Ma_c^2}{RT_c} = \frac{Z_c^2 (\beta_\gamma)_{c.p.}^2}{(C_v/R)_{c.p.}} = \left[0.289005 (C_v^0/R) + 0.247097 \right]^{-1} \quad (122)$$

THE TEMPERATURE-PRESSURE COEFFICIENT AT CONSTANT ENTHALPY OR THE JOULE-THOMSON COEFFICIENT

From a previous report (2), it can be shown that the Joule-Thomson coefficient

$$\mu = \left(\frac{\partial T}{\partial P} \right)_H \quad (123)$$

can be expressed, in reduced units, as

$$\frac{\mu P_c}{T_c} = \left(\frac{\partial \gamma}{\partial \beta} \right)_H = \frac{\gamma [\alpha Z_\alpha - \gamma Z_\gamma]}{\gamma [\alpha Z_\alpha - \gamma Z_\gamma] \beta_\gamma - \alpha \left[\frac{C_v}{R} + (Z + \gamma Z_\gamma) \right] \beta_\alpha} \quad (124)$$

Equation 124 can also be written as

$$\left(\frac{\partial \gamma}{\partial \beta} \right)_H = - \frac{Z_c (\alpha \beta_\alpha - \gamma \beta_\gamma)}{\alpha^2 \beta_\alpha (C_p/R)} \quad (125)$$

Substituting equations 23, 50, and 52 in equation 125,

$$\left(\frac{\partial \gamma}{\partial \beta} \right)_H = - \frac{1}{3(C_p/R)} \frac{[\gamma^{3/2} b(1+b\alpha)^2 - (a/2)(1-b\alpha)^2(5+3b\alpha)]}{[\gamma^{3/2}(1+b\alpha)^2 - a\alpha(1-b\alpha)^2(2+b\alpha)]} \quad (126)$$

where, from equations 88, 113, and 114,

$$\begin{aligned} \frac{C_p}{R} &= \frac{C_v}{R} + \frac{\gamma Z_c \beta_\gamma^2}{\alpha^2 \beta_\alpha} \\ &= \frac{C_v^0}{R} + \frac{3a}{4b\gamma^{3/2}} \ln(1+b\alpha) + \frac{[\gamma^{3/2}(1+b\alpha) + (a\alpha/2)(1-b\alpha)]^2}{\gamma^{3/2} [\gamma^{3/2}(1+b\alpha)^2 - a\alpha(1-b\alpha)^2(2+b\alpha)]} \end{aligned} \quad (127)$$

Equation 127 is to be used in equation 126.

At the critical point, we have from equation 124, since

$$(\beta_\alpha)_{c.p.} = 0, \quad \left[\left(\frac{\partial \gamma}{\partial \beta} \right)_H \right]_{c.p.} = \frac{1}{(\beta_\gamma)_{c.p.}} = 0.179197 \quad (128)$$

THE PRESSURE-TEMPERATURE COEFFICIENT AT CONSTANT ENTROPY

In a previous report (2), we find

$$\frac{T_c}{P_c} \left(\frac{\partial P}{\partial T} \right)_S = \left(\frac{\partial \beta}{\partial \gamma} \right)_S = \beta_\gamma + \frac{\alpha^2 C_v \beta_\alpha}{Z_c R \gamma \beta_\gamma} \quad (129)$$

Substituting equations 23, 50, 52, and 88 in equation 129,

$$\left(\frac{\partial \beta}{\partial \gamma}\right)_S = \frac{3\alpha[\gamma^{3/2}(1+b\alpha) + (a\alpha/2)(1-b\alpha)]}{\gamma^{3/2}(1-b\alpha)(1+b\alpha)} + \frac{3\alpha\left[\frac{C_v^0}{R} + \frac{3a}{4b\gamma^{3/2}} \ln(1+b\alpha)\right] \left[\gamma^{3/2}(1+b\alpha)^2 - a\alpha(1-b\alpha)^2(2+b\alpha)\right]}{(1-b\alpha)(1+b\alpha)[\gamma^{3/2}(1+b\alpha) + (a\alpha/2)(1-b\alpha)]} \quad (130)$$

At the critical point, we have from equation 129, since $(\beta_\alpha)_{c.p.} = 0$,

$$\left[\frac{T_c}{P_c} \left(\frac{\partial P}{\partial T}\right)_S\right]_{c.p.} = \left[\left(\frac{\partial \beta}{\partial \gamma}\right)_S\right]_{c.p.} = (\beta_\gamma)_{c.p.} = 5.58043 \quad (131)$$

THE VOLUME-TEMPERATURE COEFFICIENT AT CONSTANT ENTROPY

From mathematics,

$$\left(\frac{\partial V}{\partial T}\right)_S = - \frac{(\partial S / \partial T)_V}{(\partial S / \partial V)_T} \quad (132)$$

But (18)

$$\left(\frac{\partial S}{\partial V}\right)_T = \left(\frac{\partial P}{\partial T}\right)_V = \left(\frac{\partial P}{\partial T}\right)_\rho = P_T \quad ; \quad (133)$$

$$\left(\frac{\partial S}{\partial T}\right)_V = \frac{C_v}{T} \quad (134)$$

Substituting equations 133 and 134 in equation 132,

$$\left(\frac{\partial V}{\partial T}\right)_S = - \frac{C_v}{TP_T} \quad (135)$$

or, in reduced units,

$$\rho_c T_c \left(\frac{\partial V}{\partial T}\right)_S = \left(\frac{\partial(1/\alpha)}{\partial \gamma}\right)_S = - \frac{(C_v/R)}{Z_c \gamma \beta_\gamma} \quad (136)$$

Substituting equations 23, 50, and 88 in equation 136,

$$\rho_c T_c \left(\frac{\partial V}{\partial T} \right)_S = - \frac{\gamma^{1/2} (1-b\alpha) (1+b\alpha) \left[\frac{C_v^0}{R} + \frac{3a}{4b\gamma^{3/2}} \ln(1+b\alpha) \right]}{\alpha [\gamma^{3/2} (1+b\alpha) + (a\alpha/2) (1-b\alpha)]} \quad (137)$$

At the critical point,

$$\left[\rho_c T_c \left(\frac{\partial V}{\partial T} \right)_S \right]_{c.p.} = - \left[\frac{(C_v/R)}{Z_c \beta_\gamma} \right]_{c.p.} = - \left[0.537592 (C_v^0/R) + 0.459636 \right] \quad (138)$$

THE PRESSURE-VOLUME COEFFICIENT AT CONSTANT ENTROPY

From mathematics,

$$\left(\frac{\partial P}{\partial V} \right)_S = \frac{(\partial P / \partial T)_S}{(\partial V / \partial T)_S} \quad (139)$$

or, in reduced units,

$$\frac{1}{\rho_c P_c} \left(\frac{\partial P}{\partial V} \right)_S = \left(\frac{\partial \beta}{\partial (1/\alpha)} \right)_S = \left(\frac{\partial \beta}{\partial \gamma} \right)_S \bigg/ \left(\frac{\partial (1/\alpha)}{\partial \gamma} \right)_S \quad (140)$$

Substituting equations 129 and 136 in equation 140,

$$\frac{1}{\rho_c P_c} \left(\frac{\partial P}{\partial V} \right)_S = - \alpha^2 \beta_\alpha - \frac{Z_c \gamma \beta_\gamma^2}{(C_v/R)} \quad (141)$$

Substituting equations 23, 50, 52, and 88 in equation 141,

$$\begin{aligned} \frac{1}{\rho_c P_c} \left(\frac{\partial P}{\partial V} \right)_S = & - \frac{3\alpha^2 [\gamma^{3/2} (1+b\alpha)^2 - a\alpha (1-b\alpha)^2 (2+b\alpha)]}{\gamma^{1/2} (1+b\alpha)^2 (1-b\alpha)^2} \\ & - \frac{3\alpha^2 [\gamma^{3/2} (1+b\alpha) + (a\alpha/2) (1-b\alpha)]^2}{\gamma^2 (1-b\alpha)^2 (1+b\alpha)^2 \left[\frac{C_v^0}{R} + \frac{3a}{4b\gamma^{3/2}} \ln(1+b\alpha) \right]} \quad (142) \end{aligned}$$

At the critical point,

$$\left[\frac{1}{\rho_c P_c} \left(\frac{\partial P}{\partial V} \right)_S \right]_{c.p.} = - \frac{Z_c (\beta_Y)_c^2 .p.}{(C_V/R)_{c.p.}} = - \frac{1}{Z_c} \left(\frac{Ma_c^2}{RT_c} \right) \\ = -[0.096335 (C_V^0/R) + 0.0823657]^{-1} . \quad (143)$$

THE SECOND VIRIAL COEFFICIENT

In a previous Bureau report (2), the reduced second virial coefficient, B_r , is defined as

$$B_r = B\rho_c = (Z_\alpha)_{\alpha=0} . \quad (144)$$

Thus, from equation 28, evaluated at $\alpha=0$,

$$B_r = (b - aY^{-3/2}) = 0.259921 - 1.282441 Y^{-3/2} . \quad (145)$$

For the critical isotherm,

$$B_r = -1.022519 . \quad (146)$$

THE BOYLE TEMPERATURE

If we define the Boyle reduced temperature, Y_{Boyle} , as the reduced temperature where the second virial coefficient is zero, then Y_{Boyle} is given by the relation, for a Redlich-Kwong fluid,

$$b - \frac{a}{Y_{Boyle}^{3/2}} = 0 \quad (147)$$

or, with equations 21, 22, and 147,

$$Y_{Boyle} = (a/b)^{2/3} = 2.89821 . \quad (148)$$

THE THIRD VIRIAL COEFFICIENT

In a previous Bureau report (2), the reduced third virial coefficient, C_r , is defined as

$$C_r = C\rho_c^2 = (Z_{\alpha\alpha})_{\alpha=0} . \quad (149)$$

Therefore, from equation 30, evaluated at $\alpha=0$, and with a and b defined by equations 21 and 22,

$$C_r = 2b(b + a\gamma^{-3/2}) = 0.135118 + (2/3)\gamma^{-3/2} \quad (150)$$

For the critical isotherm,

$$C_r = 0.801784 \quad (151)$$

THE JOULE-THOMSON INVERSION CURVE

The Joule-Thomson curve is defined as the curve for which $\mu=0$.

From equation 124, it can be seen that μ will equal zero if

$$\alpha Z_\alpha = \gamma Z_\gamma \quad (152)$$

provided the quantity

$$\alpha \left[\frac{C_\gamma}{R} + (Z + \gamma Z_\gamma) \right] \beta_\alpha \neq 0 \quad (153)$$

From equations 28 and 29, we see that $\mu=0$ when

$$\frac{b\alpha}{(1-b\alpha)^2} = \frac{a\alpha(5 + 3b\alpha)}{2\gamma^{3/2}(1+b\alpha)^2} \quad (154)$$

or,

$$(\gamma)_{\mu=0} = \left[\frac{a(1-b\alpha)^2(5+3b\alpha)}{2b(1+b\alpha)^2} \right]^{2/3} \quad (155)$$

Substituting equation 155 in equation 26 and collecting terms, we find that

$$\begin{aligned} (\beta)_{\mu=0} &= \frac{3\alpha[5 - 4b\alpha - 5b^2\alpha^2]}{(1-b\alpha)^2(5+3b\alpha)} \left[\frac{a(1-b\alpha)^2(5+3b\alpha)}{2b(1+b\alpha)^2} \right]^{2/3}, \\ &= 3\alpha[5 - 4b\alpha - 5b^2\alpha^2] \left[\frac{a^2}{4b^2(1+b\alpha)^4(1-b\alpha)^2(5+3b\alpha)} \right]^{1/3}. \end{aligned} \quad (156)$$

The β - γ inversion curve has a maximum when $\alpha = 1.40102$, where

$\gamma = 2.20101$ and $\beta = 10.8177$.

CONDITION FOR THERMODYNAMIC EQUILIBRIUM BETWEEN COEXISTING PHASES OF A ONE-COMPONENT SYSTEM

The equations given so far apply to any single phase. We now develop relationships applicable only when two phases are in thermodynamic equilibrium, assuming the effect of a gravitational field on the thermodynamic functions is negligible. The equations to be developed in this section of the report are thus only strictly applicable to the interface region between the two phases, which may be considered at the same level in a gravitational field.

The condition for thermodynamic equilibrium between coexisting phases of a one-component system is that the three quantities pressure, temperature, and chemical potential or Gibbs free energy must be the same in each phase.

In a previous report (2), it is shown that equality of pressure and temperature of the coexisting phases requires that

$$\alpha_1 Z_1 = \alpha_3 Z_3 \quad , \quad (157)$$

where the subscript 1 refers to the gas phase and the subscript 3 refers to the liquid phase.

Substituting for Z as given by equation 24 in equation 157, we find

$$\alpha_1 \left[\frac{1}{(1-b\alpha_1)} - \frac{a\alpha_1}{\gamma^{3/2} (1+b\alpha_1)} \right] = \alpha_3 \left[\frac{1}{(1-b\alpha_3)} - \frac{a\alpha_3}{\gamma^{3/2} (1+b\alpha_3)} \right] \quad , \quad (158)$$

where the subscript on γ has been dropped since $\gamma_1 = \gamma_3 = \gamma$.

Equation 158 establishes the reduced temperature as a function of the reduced densities of the coexisting phases and can be solved for γ once α_1 and α_3 are known. Then this value of γ can be substituted into either equation 159

$$\beta = \beta_1 = 3\alpha_1 \gamma \left[\frac{1}{(1-b\alpha_1)} - \frac{a\alpha_1}{\gamma^{3/2}(1+b\alpha_1)} \right] \quad (159)$$

or equation 160

$$\beta = \beta_3 = 3\alpha_3 \gamma \left[\frac{1}{(1-b\alpha_3)} - \frac{a\alpha_3}{\gamma^{3/2}(1+b\alpha_3)} \right] \quad (160)$$

and the equilibrium reduced pressure $\beta_1 = \beta_3 = \beta$ calculated.

When the coexisting phases of a one-component system are in thermodynamic equilibrium, we are interested in the variables α_1 , α_3 , β , and γ . We then say we have a four-variable problem or system. Among these variables, we have equation 158, which insures that the reduced pressure and temperature will be the same in each phase, and either equation 159 or equation 160 for the reduced pressure.

With the Gibbs free energy being the same in each phase, we have from equation 73, for each phase

$$Z_1 + X_1 + \ln \alpha_1 = Z_3 + X_3 + \ln \alpha_3 \quad (161)$$

or, substituting equations 24 and 36 in equation 161, we have

$$(\alpha_1 - \alpha_3) \left[\frac{b}{(1-b\alpha_1)(1-b\alpha_3)} - \frac{a}{\gamma^{3/2}(1+b\alpha_1)(1+b\alpha_3)} \right] = \ln \frac{\alpha_3(1-b\alpha_1)}{\alpha_1(1-b\alpha_3)} + \frac{a}{b\gamma^{3/2}} \ln \frac{(1+b\alpha_1)}{(1+b\alpha_3)} \quad (162)$$

Equations 158, 162, and either equation 159 or equation 160

give a total of three equations between the four quantities α_1 , α_3 , β , and γ . With two phases in equilibrium, a single component system is said, therefore, to have one degree of freedom.

Equations 158 and 162 are the functional relationships between α_1 and α_3 , when vapor and liquid coexist in equilibrium for a Redlich-Kwong fluid, as a function of γ . These two equations must be solved for the equilibrium reduced densities as a function of the reduced temperature before any of the other two-phase thermodynamic properties can be calculated.

METHOD FOR OBTAINING THE SOLUTIONS OF THE FUNCTIONAL RELATIONSHIPS BETWEEN THE EQUILIBRIUM REDUCED DENSITIES AND THE EQUILIBRIUM REDUCED TEMPERATURE OF THE COEXISTING PHASES

Since the relationships given by equations 157 and 161, which assume the form as given by equations 158 and 162 for a Redlich-Kwong fluid, are nonlinear ones, it is necessary to solve them using an iterative technique. We did this in the following way. The functions

$$\theta = \theta(\alpha_1, \alpha_3, \gamma) = \alpha_1 Z_1 - \alpha_3 Z_3 = 0 \quad (163)$$

and

$$\varphi = \varphi(\alpha_1, \alpha_3, \gamma) = Z_1 - Z_3 + X_1 - X_3 + \ln \frac{\alpha_1}{\alpha_3} = 0 \quad (164)$$

were formed, a value for γ was specified, and the problem then was to find values for α_1 and α_3 that reduced θ and φ to zero.

The method of numerical calculation of the reduced densities of the coexisting phases involved expanding θ and φ in a truncated Taylor's expansion about an approximate solution, denoted by an

also a list of three equations between the four quantities x, y, z .

With two phases in equilibrium, a single component system

is said, therefore, to have one degree of freedom.

From this it follows that the thermodynamic relations

for a single component system in equilibrium with a

single phase liquid, as a function of T . These two equations must

be solved for the equilibrium temperature as a function of the

external temperature before any of the other thermodynamic

properties can be calculated.

Before we attempt to determine the function of the thermodynamic

properties of a single component system in equilibrium with a

single phase liquid, we must first determine the

functions of the thermodynamic properties given by equations 157 and 161, which

assume the form as given by equations 155 and 161 for a single-phase

liquid, are nonlinear ones, it is necessary to solve them using an

iterative technique. We did this in the following way. The functions

$$f = f(T, P, V) = 0, \quad g = g(T, P, V) = 0 \quad (157)$$

and

$$h = h(T, P, V) = 0, \quad i = i(T, P, V) = 0 \quad (158)$$

were solved, a value for T was specified, and the problem then was

to find values for P and V that reduced f and g to zero.

The method of numerical calculation of the reduced densities

of the coexisting phases involved expanding f and g in a truncated

Taylor's expansion about an appropriate solution, denoted by an

asterisk, and solving the two equations

$$-\theta^* = \theta_{\alpha(1)}^* \Delta\alpha_1 + \theta_{\alpha(3)}^* \Delta\alpha_3 \quad (165)$$

and

$$-\varphi^* = \varphi_{\alpha(1)}^* \Delta\alpha_1 + \varphi_{\alpha(3)}^* \Delta\alpha_3 \quad (166)$$

for the corrections, $\Delta\alpha_1$ and $\Delta\alpha_3$, to be applied to the initial estimates assumed in the beginning. In equations 165 and 166,

$$\theta_{\alpha(1)} = \left(\frac{\partial \theta}{\partial \alpha_1} \right)_{\gamma, \alpha_3} = Z_1 + \alpha_1 Z_{\alpha(1)} = \frac{1}{(1-b\alpha_1)^2} - \frac{a\alpha_1(2+b\alpha_1)}{\gamma^{3/2}(1+b\alpha_1)^2}, \quad (167)$$

$$\theta_{\alpha(3)} = \left(\frac{\partial \theta}{\partial \alpha_3} \right)_{\gamma, \alpha_1} = -Z_3 - \alpha_3 Z_{\alpha(3)} = -\frac{1}{(1-b\alpha_3)^2} + \frac{a\alpha_3(2+b\alpha_3)}{\gamma^{3/2}(1+b\alpha_3)^2}, \quad (168)$$

$$\begin{aligned} \varphi_{\alpha(1)} &= \left(\frac{\partial \varphi}{\partial \alpha_1} \right)_{\gamma, \alpha_3} = Z_{\alpha(1)} + X_{\alpha(1)} + \frac{1}{\alpha_1}, \\ &= Z_{\alpha(1)} + \frac{Z_1}{\alpha_1} = \frac{1}{\alpha_1(1-b\alpha_1)^2} - \frac{a(2+b\alpha_1)}{\gamma^{3/2}(1+b\alpha_1)^2}, \end{aligned} \quad (169)$$

and

$$\begin{aligned} \varphi_{\alpha(3)} &= \left(\frac{\partial \varphi}{\partial \alpha_3} \right)_{\gamma, \alpha_1} = -Z_{\alpha(3)} - X_{\alpha(3)} - \frac{1}{\alpha_3}, \\ &= -Z_{\alpha(3)} - \frac{Z_3}{\alpha_3} = -\frac{1}{\alpha_3(1-b\alpha_3)^2} + \frac{a(2+b\alpha_3)}{\gamma^{3/2}(1+b\alpha_3)^2}. \end{aligned} \quad (170)$$

The corrections $\Delta\alpha_1$ and $\Delta\alpha_3$, are given by

$$\Delta\alpha_1 = \alpha_1 - (\alpha_1)^* ; \quad (171)$$

$$\Delta\alpha_3 = \alpha_3 - (\alpha_3)^* . \quad (172)$$

All calculations were repeated using $[\Delta\alpha_1 + (\alpha_1)^*]$ and $[\Delta\alpha_3 + (\alpha_3)^*]$ for the start of a new iteration. This iterative procedure was repeated until $\theta = \varphi = 0$ to within some predetermined small quantity.

The method outlined in this section was used to solve equations 163 and 164 for the equilibrium reduced densities of the coexisting phases for $0.10 \leq \gamma \leq 0.9999$. A parametric search technique (8) was used to generate initial estimates for α_1 and α_3 .

COEXISTENCE CURVE OF SATURATED LIQUID AND VAPOR DENSITIES AND VOLUMES AS A FUNCTION OF TEMPERATURE

Table 1 gives values, in reduced variables, of the densities of saturated liquid and vapor and of the rectilinear diameter⁴, which

⁴A very thorough discussion of rectilinear diameter is given in reference 20.

is just the arithmetic average density of coexisting liquid and vapor, as a function of temperature. These data, illustrated in figure 1, clearly show that the slope of the rectilinear diameter,

FIGURE 1. - Redlich-Kwong fluid, saturated densities as a function of temperature.

for a Redlich-Kwong fluid, is not zero at the critical point.

TABLE 1. - REDLICH-KWONG FLUID, SATURATED DENSITIES AS A FUNCTION OF TEMPERATURE

$$\gamma = T/T_c$$

$$\alpha = \rho/\rho_c$$

γ	α_1	α_3	$\frac{\alpha_1 + \alpha_3}{2}$
0.00000E-99	0.00000E-00	3.84732E-00	1.92366E-00
1.00000E-01	3.19688E-45	3.79768E-00	1.89884E-00
1.50000E-01	4.35545E-24	3.75561E-00	1.87780E-00
2.00000E-01	2.55749E-15	3.70515E-00	1.85257E-00
2.50000E-01	9.57415E-11	3.64702E-00	1.82351E-00
3.00000E-01	5.00887E-08	3.58155E-00	1.79077E-00
3.50000E-01	2.87741E-06	3.50882E-00	1.75441E-00
4.00000E-01	4.64669E-05	3.42870E-00	1.71437E-00
4.50000E-01	3.42344E-04	3.34087E-00	1.67060E-00
5.00000E-01	1.51327E-03	3.24479E-00	1.62315E-00
5.50000E-01	4.74144E-03	3.13971E-00	1.57222E-00
6.00000E-01	1.17179E-02	3.02460E-00	1.51816E-00
6.50000E-01	2.45197E-02	2.89809E-00	1.46130E-00
7.00000E-01	4.55903E-02	2.75834E-00	1.40196E-00
7.50000E-01	7.79320E-02	2.60278E-00	1.34035E-00
8.00000E-01	1.25623E-01	2.42756E-00	1.27659E-00
8.50000E-01	1.95020E-01	2.22642E-00	1.21072E-00
9.00000E-01	2.97983E-01	1.98745E-00	1.14271E-00
9.50000E-01	4.64356E-01	1.68067E-00	1.07251E-00
9.52000E-01	4.73365E-01	1.66595E-00	1.06965E-00
9.54000E-01	4.82647E-01	1.65095E-00	1.06679E-00
9.56000E-01	4.92219E-01	1.63565E-00	1.06393E-00
9.58000E-01	5.02102E-01	1.62003E-00	1.06107E-00
9.60000E-01	5.12317E-01	1.60408E-00	1.05820E-00
9.62000E-01	5.22889E-01	1.58776E-00	1.05532E-00
9.64000E-01	5.33847E-01	1.57104E-00	1.05244E-00
9.66000E-01	5.45222E-01	1.55391E-00	1.04956E-00
9.68000E-01	5.57050E-01	1.53631E-00	1.04668E-00
9.70000E-01	5.69376E-01	1.51820E-00	1.04379E-00
9.72000E-01	5.82248E-01	1.49955E-00	1.04090E-00
9.74000E-01	5.95725E-01	1.48028E-00	1.03800E-00
9.76000E-01	6.09878E-01	1.46032E-00	1.03510E-00
9.78000E-01	6.24792E-01	1.43960E-00	1.03219E-00
9.80000E-01	6.40572E-01	1.41801E-00	1.02929E-00
9.82000E-01	6.57350E-01	1.39540E-00	1.02637E-00
9.84000E-01	6.75297E-01	1.37163E-00	1.02346E-00
9.86000E-01	6.94637E-01	1.34645E-00	1.02054E-00
9.88000E-01	7.15679E-01	1.31956E-00	1.01762E-00
9.90000E-01	7.38868E-01	1.29051E-00	1.01469E-00
9.92000E-01	7.64885E-01	1.25863E-00	1.01176E-00
9.94000E-01	7.94877E-01	1.22277E-00	1.00882E-00
9.96000E-01	8.31078E-01	1.18069E-00	1.00588E-00
9.98000E-01	8.79251E-01	1.12664E-00	1.00294E-00
9.99000E-01	9.13977E-01	1.08896E-00	1.00147E-00
1.00000E-00	1.00000E-00	1.00000E-00	1.00000E-00

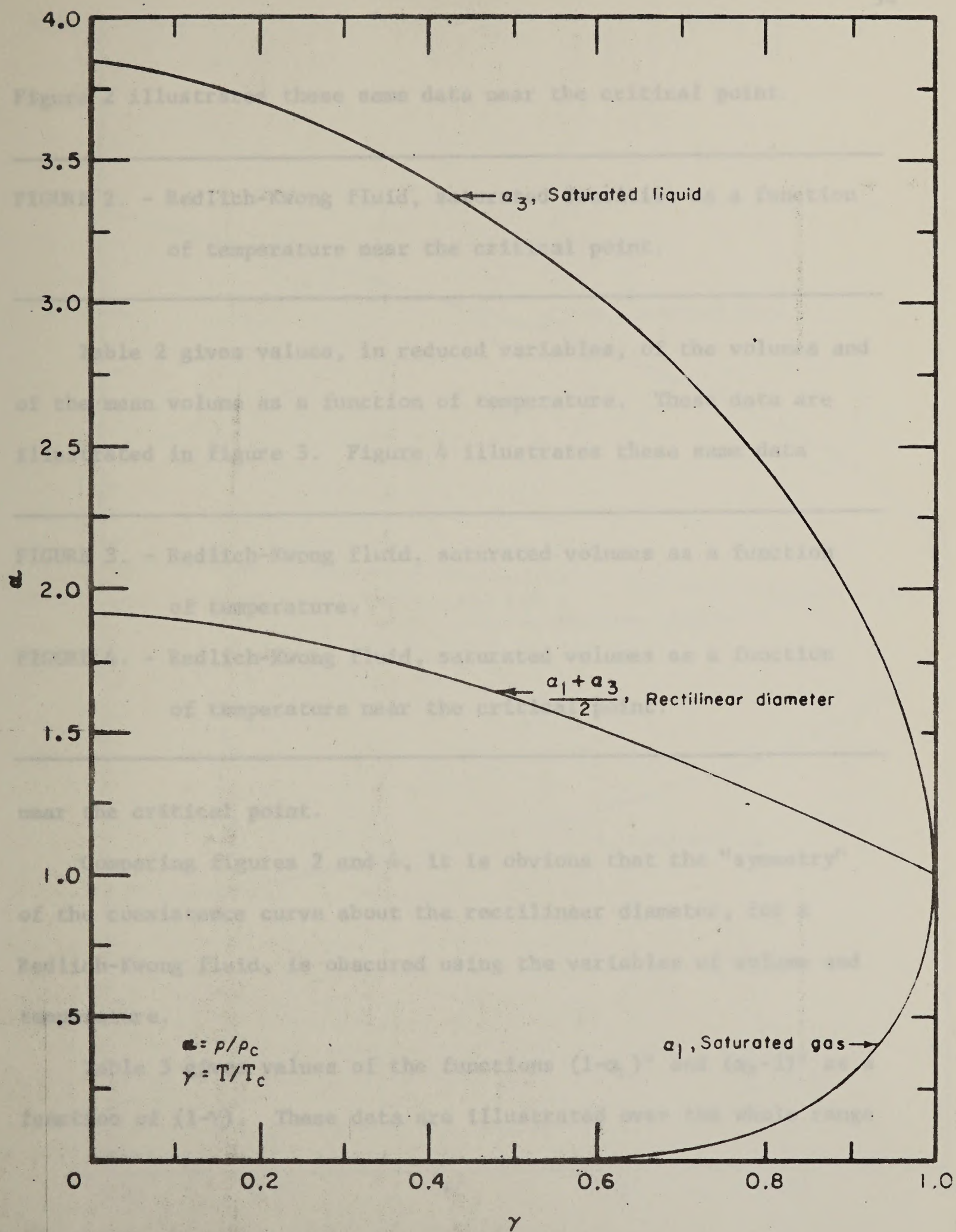


FIGURE 1. - Redlich-Kwong Fluid, Saturated Densities as a Function of Temperature.

Figure 2 illustrates these same data near the critical point.

FIGURE 2. - Redlich-Kwong fluid, saturated densities as a function of temperature near the critical point.

Table 2 gives values, in reduced variables, of the volumes and of the mean volume as a function of temperature. These data are illustrated in figure 3. Figure 4 illustrates these same data

FIGURE 3. - Redlich-Kwong fluid, saturated volumes as a function of temperature.

FIGURE 4. - Redlich-Kwong fluid, saturated volumes as a function of temperature near the critical point.

near the critical point.

Comparing figures 2 and 4, it is obvious that the "symmetry" of the coexistence curve about the rectilinear diameter, for a Redlich-Kwong fluid, is obscured using the variables of volume and temperature.

Table 3 gives values of the functions $(1-\alpha_1)^2$ and $(\alpha_3-1)^2$ as a function of $(1-\gamma)$. These data are illustrated over the whole range

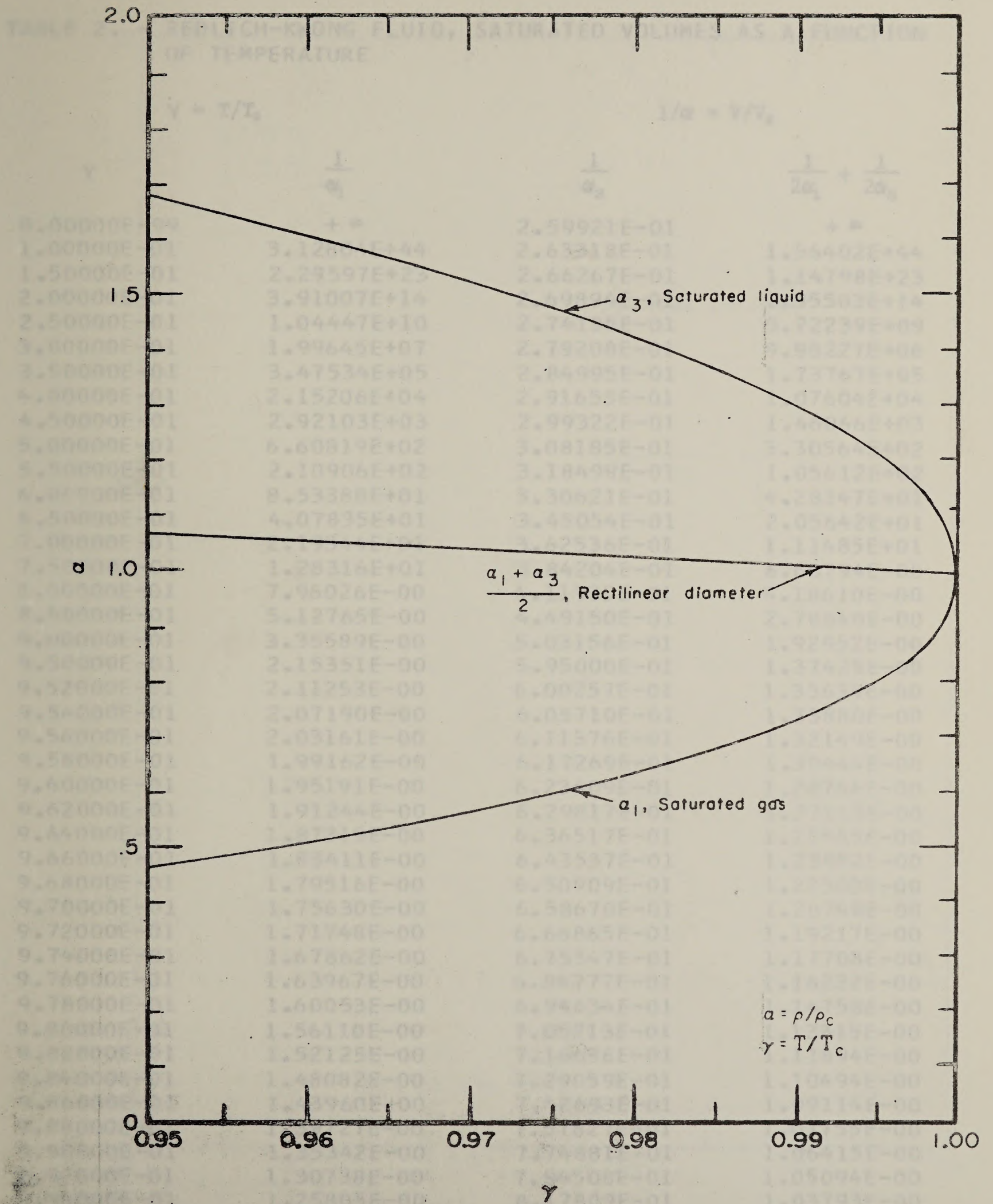


FIGURE 2.—Redlich - Kwong Fluid, Saturated Densities as a Function of Temperature Near the Critical Point.

TABLE 2. - REDLICH-KWONG FLUID, SATURATED VOLUMES AS A FUNCTION OF TEMPERATURE

$$\gamma = T/T_c$$

$$1/\alpha = V/V_c$$

γ	$\frac{1}{\alpha_1}$	$\frac{1}{\alpha_3}$	$\frac{1}{2\alpha_1} + \frac{1}{2\alpha_3}$
0.00000E-99	+ ∞	2.59921E-01	+ ∞
1.00000E-01	3.12804E+44	2.63318E-01	1.56402E+44
1.50000E-01	2.29597E+23	2.66267E-01	1.14798E+23
2.00000E-01	3.91007E+14	2.69894E-01	1.95503E+14
2.50000E-01	1.04447E+10	2.74195E-01	5.22239E+09
3.00000E-01	1.99645E+07	2.79208E-01	9.98227E+06
3.50000E-01	3.47534E+05	2.84995E-01	1.73767E+05
4.00000E-01	2.15206E+04	2.91655E-01	1.07604E+04
4.50000E-01	2.92103E+03	2.99322E-01	1.46066E+03
5.00000E-01	6.60819E+02	3.08185E-01	3.30564E+02
5.50000E-01	2.10906E+02	3.18499E-01	1.05612E+02
6.00000E-01	8.53388E+01	3.30621E-01	4.28347E+01
6.50000E-01	4.07835E+01	3.45054E-01	2.05642E+01
7.00000E-01	2.19344E+01	3.62536E-01	1.11485E+01
7.50000E-01	1.28316E+01	3.84204E-01	6.60794E-00
8.00000E-01	7.96026E-00	4.11935E-01	4.18610E-00
8.50000E-01	5.12765E-00	4.49150E-01	2.78840E-00
9.00000E-01	3.35589E-00	5.03156E-01	1.92952E-00
9.50000E-01	2.15351E-00	5.95000E-01	1.37425E-00
9.52000E-01	2.11253E-00	6.00257E-01	1.35639E-00
9.54000E-01	2.07190E-00	6.05710E-01	1.33880E-00
9.56000E-01	2.03161E-00	6.11376E-01	1.32149E-00
9.58000E-01	1.99162E-00	6.17269E-01	1.30444E-00
9.60000E-01	1.95191E-00	6.23409E-01	1.28766E-00
9.62000E-01	1.91244E-00	6.29817E-01	1.27113E-00
9.64000E-01	1.87319E-00	6.36517E-01	1.25485E-00
9.66000E-01	1.83411E-00	6.43537E-01	1.23882E-00
9.68000E-01	1.79516E-00	6.50909E-01	1.22303E-00
9.70000E-01	1.75630E-00	6.58670E-01	1.20748E-00
9.72000E-01	1.71748E-00	6.66865E-01	1.19217E-00
9.74000E-01	1.67862E-00	6.75547E-01	1.17708E-00
9.76000E-01	1.63967E-00	6.84777E-01	1.16222E-00
9.78000E-01	1.60053E-00	6.94634E-01	1.14758E-00
9.80000E-01	1.56110E-00	7.05213E-01	1.13315E-00
9.82000E-01	1.52125E-00	7.16636E-01	1.11894E-00
9.84000E-01	1.48082E-00	7.29059E-01	1.10494E-00
9.86000E-01	1.43960E-00	7.42693E-01	1.09114E-00
9.88000E-01	1.39727E-00	7.57827E-01	1.07755E-00
9.90000E-01	1.35342E-00	7.74881E-01	1.06415E-00
9.92000E-01	1.30738E-00	7.94508E-01	1.05094E-00
9.94000E-01	1.25805E-00	8.17809E-01	1.03793E-00
9.96000E-01	1.20325E-00	8.46955E-01	1.02510E-00
9.98000E-01	1.13733E-00	8.87593E-01	1.01246E-00
9.99000E-01	1.09411E-00	9.18299E-01	1.00620E-00
1.00000E-00	1.00000E-00	1.00000E-00	1.00000E-00

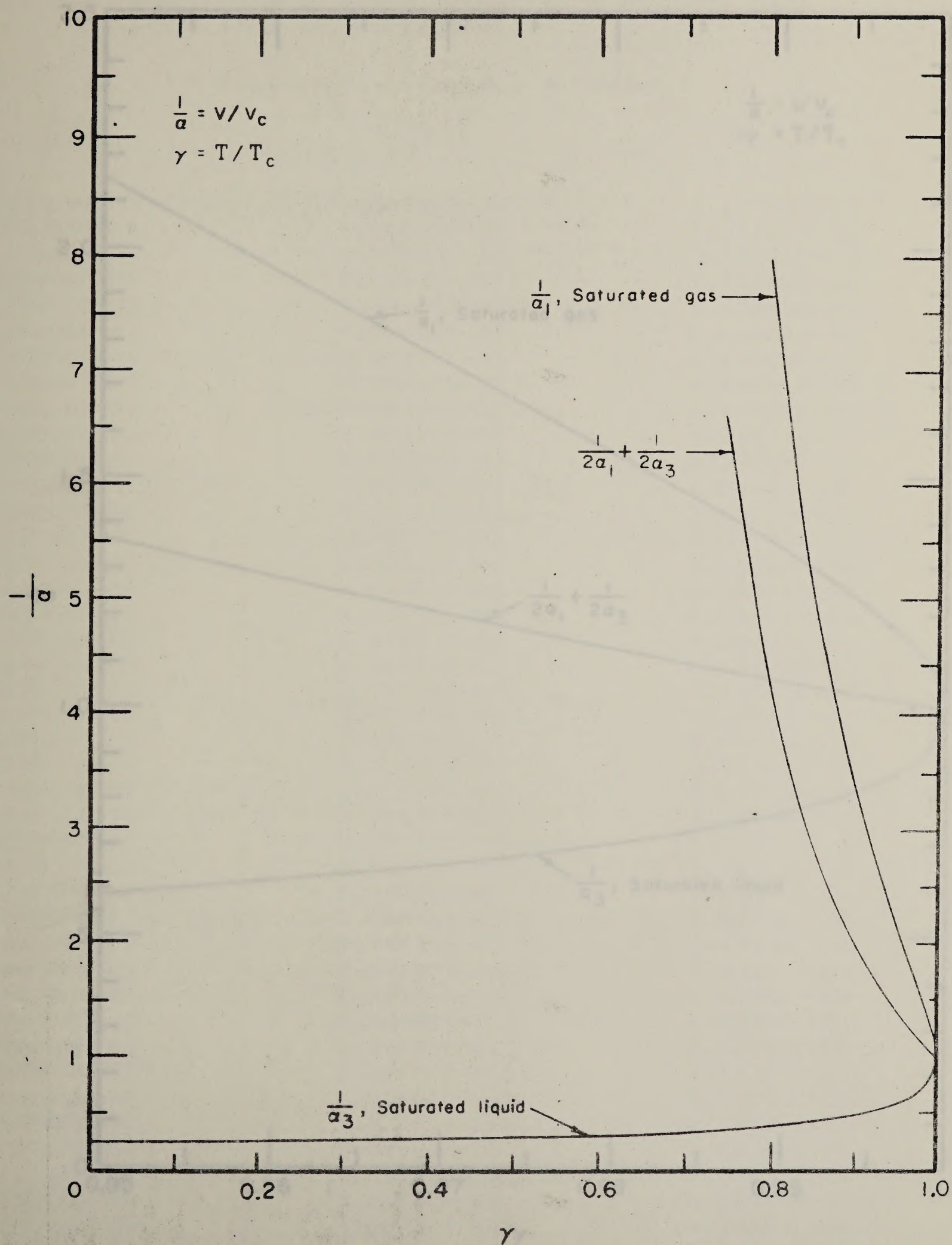


FIGURE 3.- Redlich - Kwong Fluid, Saturated Volumes as a Function of Temperature.

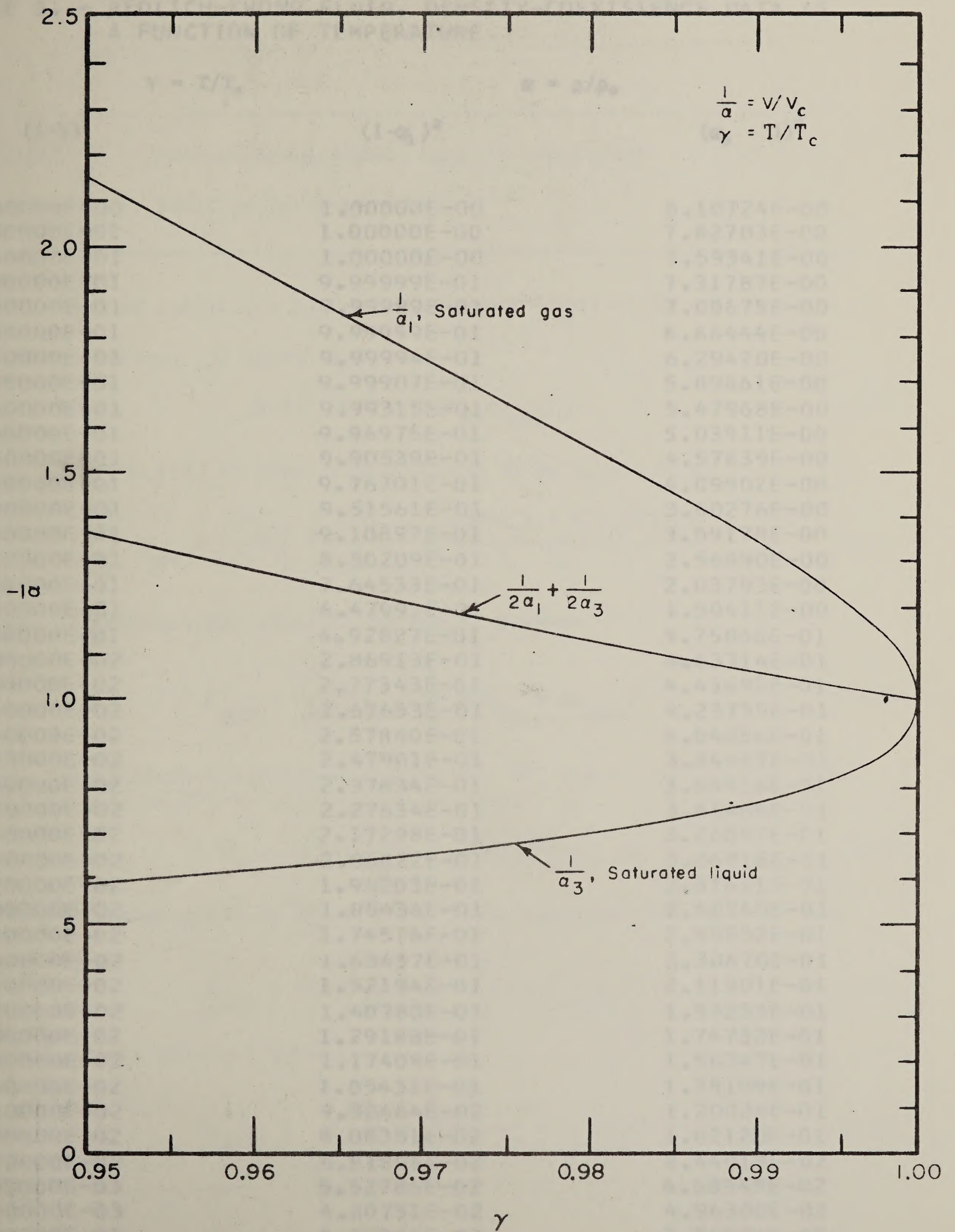


FIGURE 4.- Redlich - Kwong Fluid, Saturated Volumes as a Function of Temperature Near the Critical Point.

TABLE 3. - REDLICH-KWONG FLUID, DENSITY-COEXISTENCE DATA AS A FUNCTION OF TEMPERATURE

$\gamma = T/T_c$	$\alpha = \rho/\rho_c$	
(1- γ)	(1- α_1) ²	($\alpha_3 - 1$) ²
1.00000E-00	1.00000E-00	8.10724E-00
9.00000E-01	1.00000E-00	7.82703E-00
8.50000E-01	1.00000E-00	7.59341E-00
8.00000E-01	9.99999E-01	7.31787E-00
7.50000E-01	9.99999E-01	7.00675E-00
7.00000E-01	9.99999E-01	6.66444E-00
6.50000E-01	9.99994E-01	6.29420E-00
6.00000E-01	9.99907E-01	5.89861E-00
5.50000E-01	9.99315E-01	5.47968E-00
5.00000E-01	9.96975E-01	5.03911E-00
4.50000E-01	9.90539E-01	4.57839E-00
4.00000E-01	9.76701E-01	4.09902E-00
3.50000E-01	9.51561E-01	3.60276E-00
3.00000E-01	9.10897E-01	3.09178E-00
2.50000E-01	8.50209E-01	2.56890E-00
2.00000E-01	7.64533E-01	2.03793E-00
1.50000E-01	6.47991E-01	1.50411E-00
1.00000E-01	4.92827E-01	9.75066E-01
5.00000E-02	2.86913E-01	4.63314E-01
4.80000E-02	2.77343E-01	4.43492E-01
4.60000E-02	2.67653E-01	4.23739E-01
4.40000E-02	2.57840E-01	4.04056E-01
4.20000E-02	2.47901E-01	3.84447E-01
4.00000E-02	2.37834E-01	3.64916E-01
3.80000E-02	2.27634E-01	3.45464E-01
3.60000E-02	2.17298E-01	3.26097E-01
3.40000E-02	2.06822E-01	3.06818E-01
3.20000E-02	1.96203E-01	2.87631E-01
3.00000E-02	1.85436E-01	2.68540E-01
2.80000E-02	1.74516E-01	2.49552E-01
2.60000E-02	1.63437E-01	2.30670E-01
2.40000E-02	1.52194E-01	2.11901E-01
2.20000E-02	1.40780E-01	1.93253E-01
2.00000E-02	1.29188E-01	1.74732E-01
1.80000E-02	1.17408E-01	1.56347E-01
1.60000E-02	1.05431E-01	1.38109E-01
1.40000E-02	9.32464E-02	1.20028E-01
1.20000E-02	8.08381E-02	1.02120E-01
1.00000E-02	6.81896E-02	8.44013E-02
8.00000E-03	5.52786E-02	6.68945E-02
6.00000E-03	4.20751E-02	4.96300E-02
4.00000E-03	2.85344E-02	3.26524E-02
2.00000E-03	1.45802E-02	1.60381E-02
1.00000E-03	7.39984E-03	7.91564E-03
0.00000E-99	0.00000E-99	0.00000E-99

of variables in figure 5.

FIGURE 5. - Redlich-Kwong fluid, density-coexistence data as a function of temperature.

For an analytical fluid sufficiently close to the critical point, Barieau (3) shows that

$$(\alpha-1)^2 = 6(1-\gamma)(\beta_{\alpha\gamma}/\beta_{\alpha\alpha\alpha})_{c.p.} \quad (173)$$

In equation 173, we have from equation 50 or equation 52

$$\beta_{\alpha\gamma} = \left(\frac{\partial \beta_{\alpha}}{\partial \gamma} \right)_{\alpha} = \left(\frac{\partial \beta_{\gamma}}{\partial \alpha} \right)_{\gamma} = \frac{(Z + \gamma Z_{\gamma}) + \alpha(Z_{\alpha} + \gamma Z_{\alpha\gamma})}{Z_c} \quad (174)$$

and differentiating equation 52 twice, we have

$$\beta_{\alpha\alpha\alpha} = \left(\frac{\partial^2 \beta_{\alpha}}{\partial \alpha^2} \right)_{\gamma} = \frac{\gamma}{Z_c} [3Z_{\alpha\alpha} + \alpha Z_{\alpha\alpha\alpha}] \quad (175)$$

Substituting equations 23, 24, 28, 29, and 31 in equation 174,

$$\beta_{\alpha\gamma} = 3 \left[\frac{1}{(1-b\alpha)^2} + \frac{a\alpha(2+b\alpha)}{2\gamma^{3/2}(1+b\alpha)^2} \right] \quad (176)$$

Substituting equations 23, 30, and 33 in equation 175, we find that

$$\beta_{\alpha\alpha\alpha} = 18b\gamma \left[\frac{b}{(1-b\alpha)^4} + \frac{a}{\gamma^{3/2}(1+b\alpha)^4} \right] \quad (177)$$

At the critical point,

$$(\beta_{\alpha\gamma})_{c.p.} = \frac{(Z_{\gamma} + Z_{\alpha\gamma})_{c.p.}}{Z_c} = 8.21592 \quad (178)$$

and

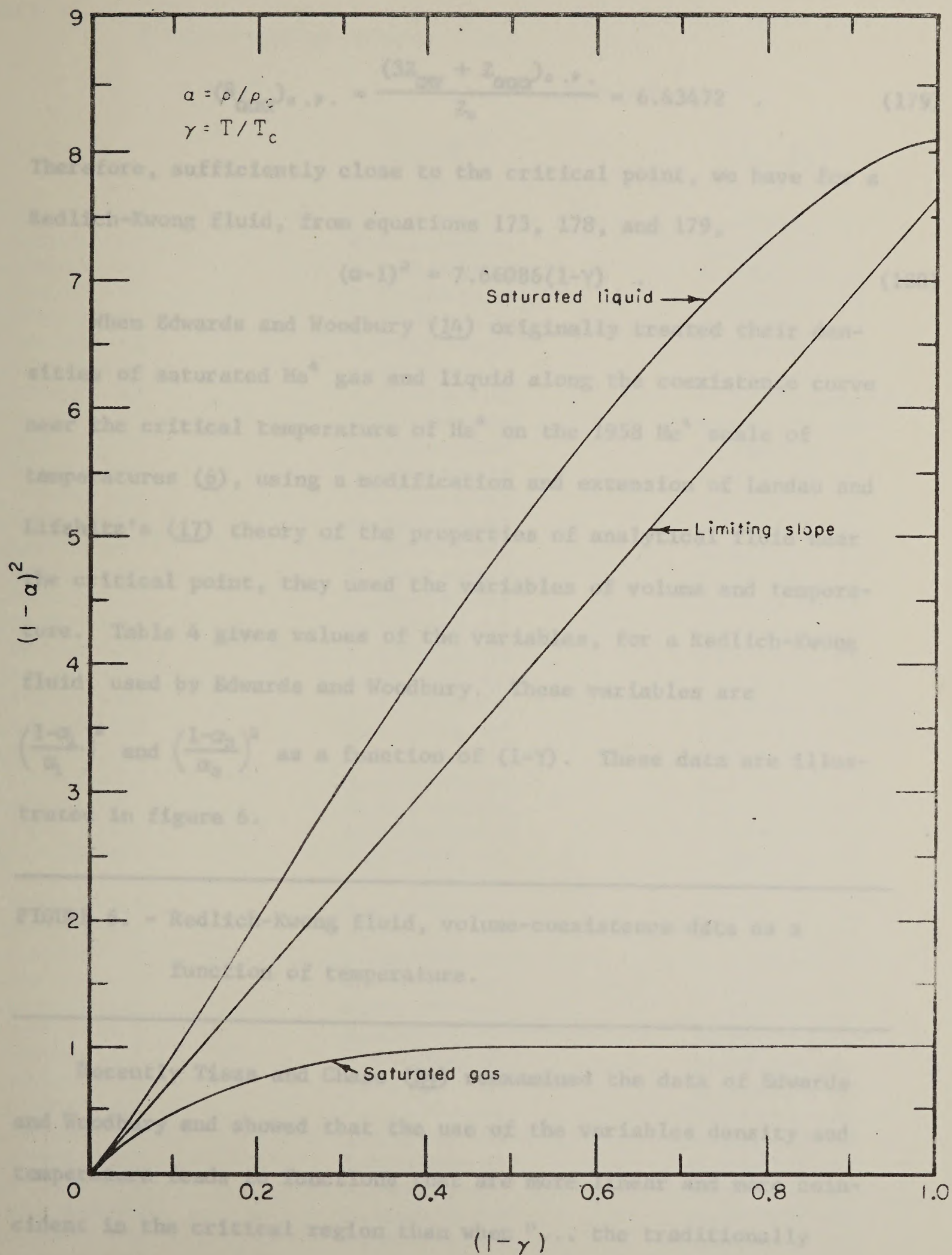


FIGURE 5.- Redlich-Kwong Fluid, Density-Coexistence Data as a Function of Temperature.

$$(\beta_{\alpha\alpha\alpha})_{c.p.} = \frac{(3Z_{\alpha\alpha} + Z_{\alpha\alpha\alpha})_{c.p.}}{Z_c} = 6.43472 \quad (179)$$

Therefore, sufficiently close to the critical point, we have for a Redlich-Kwong fluid, from equations 173, 178, and 179,

$$(\alpha-1)^2 = 7.66086(1-\gamma) \quad (180)$$

When Edwards and Woodbury (14) originally treated their densities of saturated He^4 gas and liquid along the coexistence curve near the critical temperature of He^4 on the 1958 He^4 scale of temperatures (6), using a modification and extension of Landau and Lifshitz's (17) theory of the properties of analytical fluid near the critical point, they used the variables of volume and temperature. Table 4 gives values of the variables, for a Redlich-Kwong fluid, used by Edwards and Woodbury. These variables are

$\left(\frac{1-\alpha_1}{\alpha_1}\right)^2$ and $\left(\frac{1-\alpha_3}{\alpha_3}\right)^2$ as a function of $(1-\gamma)$. These data are illustrated in figure 6.

FIGURE 6. - Redlich-Kwong fluid, volume-coexistence data as a function of temperature.

Recently Tisza and Chase (24) reexamined the data of Edwards and Woodbury and showed that the use of the variables density and temperature leads to functions that are more linear and more coincident in the critical region than when "... the traditionally

TABLE 4. - REDLICH-KWONG FLUID, VOLUME-COEXISTENCE DATA AS A FUNCTION OF TEMPERATURE

$$\gamma = T/T_c$$

$$1/\alpha = V/V_c$$

$(1-\gamma)$	$\left[\frac{1 - \alpha_1}{\alpha_1} \right]^2$	$\left[\frac{1 - \alpha_3}{\alpha_3} \right]^2$
1.00000E-00	$+\infty$	5.47716E-01
9.00000E-01	9.78468E+88	5.42699E-01
8.50000E-01	5.27149E+46	5.38362E-01
8.00000E-01	1.52886E+29	5.33054E-01
7.50000E-01	1.09093E+20	5.26791E-01
7.00000E-01	3.98583E+14	5.19540E-01
6.50000E-01	1.20779E+11	5.11231E-01
6.00000E-01	4.63095E+08	5.01752E-01
5.50000E-01	8.52658E+06	4.90948E-01
5.00000E-01	4.35362E+05	4.78607E-01
4.50000E-01	4.40605E+04	4.64442E-01
4.00000E-01	7.11304E+03	4.48067E-01
3.50000E-01	1.58272E+03	4.28954E-01
3.00000E-01	4.38252E+02	4.06360E-01
2.50000E-01	1.39988E+02	3.79204E-01
2.00000E-01	4.84453E+01	3.45819E-01
1.50000E-01	1.70375E+01	3.03434E-01
1.00000E-01	5.55021E-00	2.46853E-01
5.00000E-02	1.33060E-00	1.64024E-01
4.80000E-02	1.23772E-00	1.59794E-01
4.60000E-02	1.14898E-00	1.55463E-01
4.40000E-02	1.06422E-00	1.51028E-01
4.20000E-02	9.83320E-01	1.46482E-01
4.00000E-02	9.06140E-01	1.41820E-01
3.80000E-02	8.32562E-01	1.37035E-01
3.60000E-02	7.62468E-01	1.32119E-01
3.40000E-02	6.95747E-01	1.27065E-01
3.20000E-02	6.32292E-01	1.21864E-01
3.00000E-02	5.72001E-01	1.16505E-01
2.80000E-02	5.14778E-01	1.10978E-01
2.60000E-02	4.60532E-01	1.05269E-01
2.40000E-02	4.09179E-01	9.93651E-02
2.20000E-02	3.60639E-01	9.32480E-02
2.00000E-02	3.14838E-01	8.68990E-02
1.80000E-02	2.71710E-01	8.02950E-02
1.60000E-02	2.31197E-01	7.34087E-02
1.40000E-02	1.93248E-01	6.62068E-02
1.20000E-02	1.57826E-01	5.86477E-02
1.00000E-02	1.24906E-01	5.06781E-02
8.00000E-03	9.44853E-02	4.22267E-02
6.00000E-03	6.65923E-02	3.31932E-02
4.00000E-03	4.13128E-02	2.34226E-02
2.00000E-03	1.88599E-02	1.26352E-02
1.00000E-03	8.85832E-03	6.67504E-03
0.00000E-99	0.00000E-99	0.00000E-99

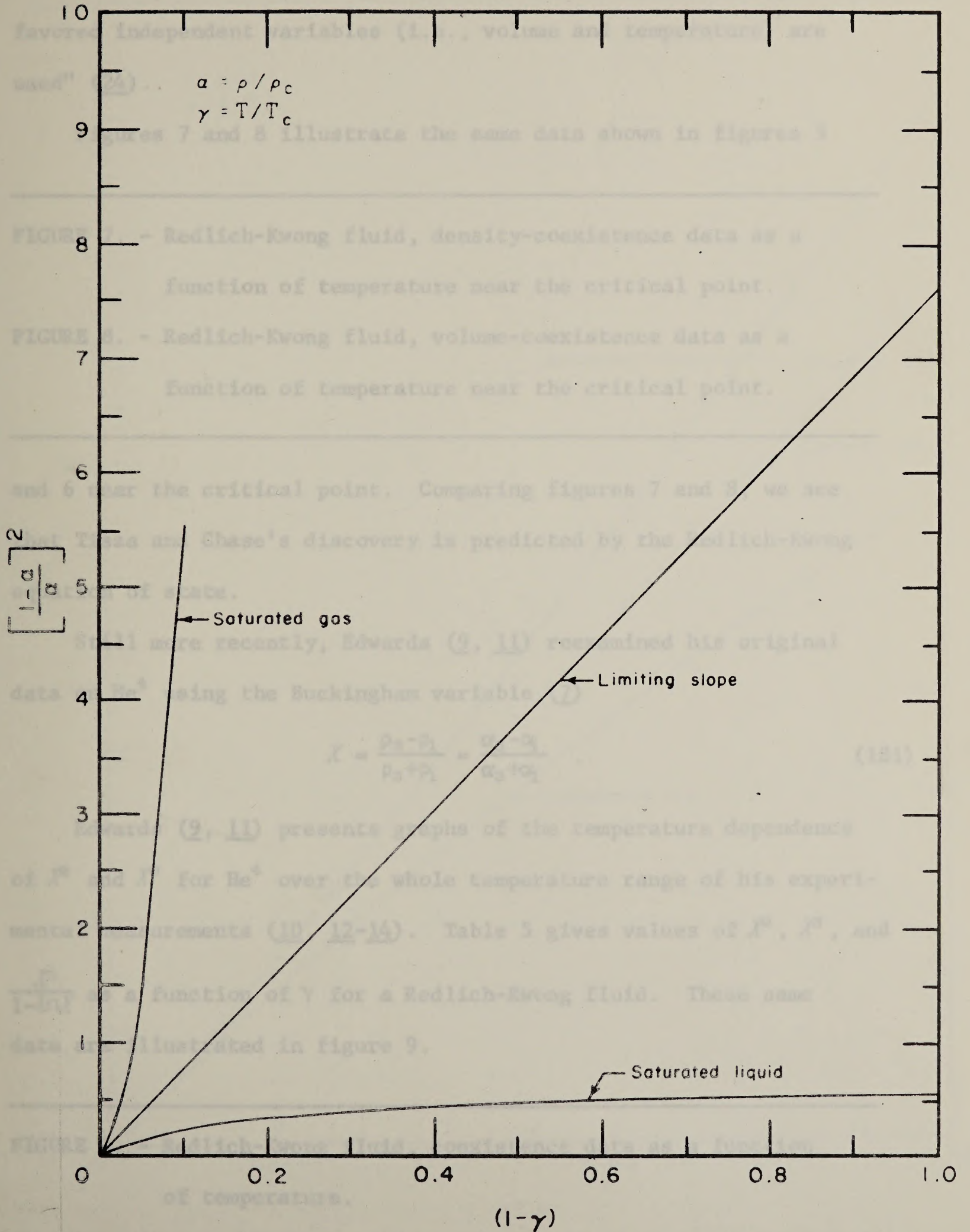


FIGURE 6. — Redlich-Kwong Fluid, Volume-Coexistence Data as a Function of Temperature.

avored independent variables (i.e., volume and temperature) are used" (24).

Figures 7 and 8 illustrate the same data shown in figures 5

FIGURE 7. - Redlich-Kwong fluid, density-coexistence data as a function of temperature near the critical point.

FIGURE 8. - Redlich-Kwong fluid, volume-coexistence data as a function of temperature near the critical point.

and 6 near the critical point. Comparing figures 7 and 8, we see that Tisza and Chase's discovery is predicted by the Redlich-Kwong equation of state.

Still more recently, Edwards (9, 11) reexamined his original data on He^4 using the Buckingham variable (7)

$$X = \frac{\rho_3 - \rho_1}{\rho_3 + \rho_1} = \frac{\alpha_3 - \alpha_1}{\alpha_3 + \alpha_1} \quad (181)$$

Edwards (9, 11) presents graphs of the temperature dependence of X^2 and X^3 for He^4 over the whole temperature range of his experimental measurements (10, 12-14). Table 5 gives values of X^2 , X^3 , and $\frac{X^2}{1 - \ln X}$ as a function of γ for a Redlich-Kwong fluid. These same data are illustrated in figure 9.

FIGURE 9. - Redlich-Kwong fluid, coexistence data as a function of temperature.

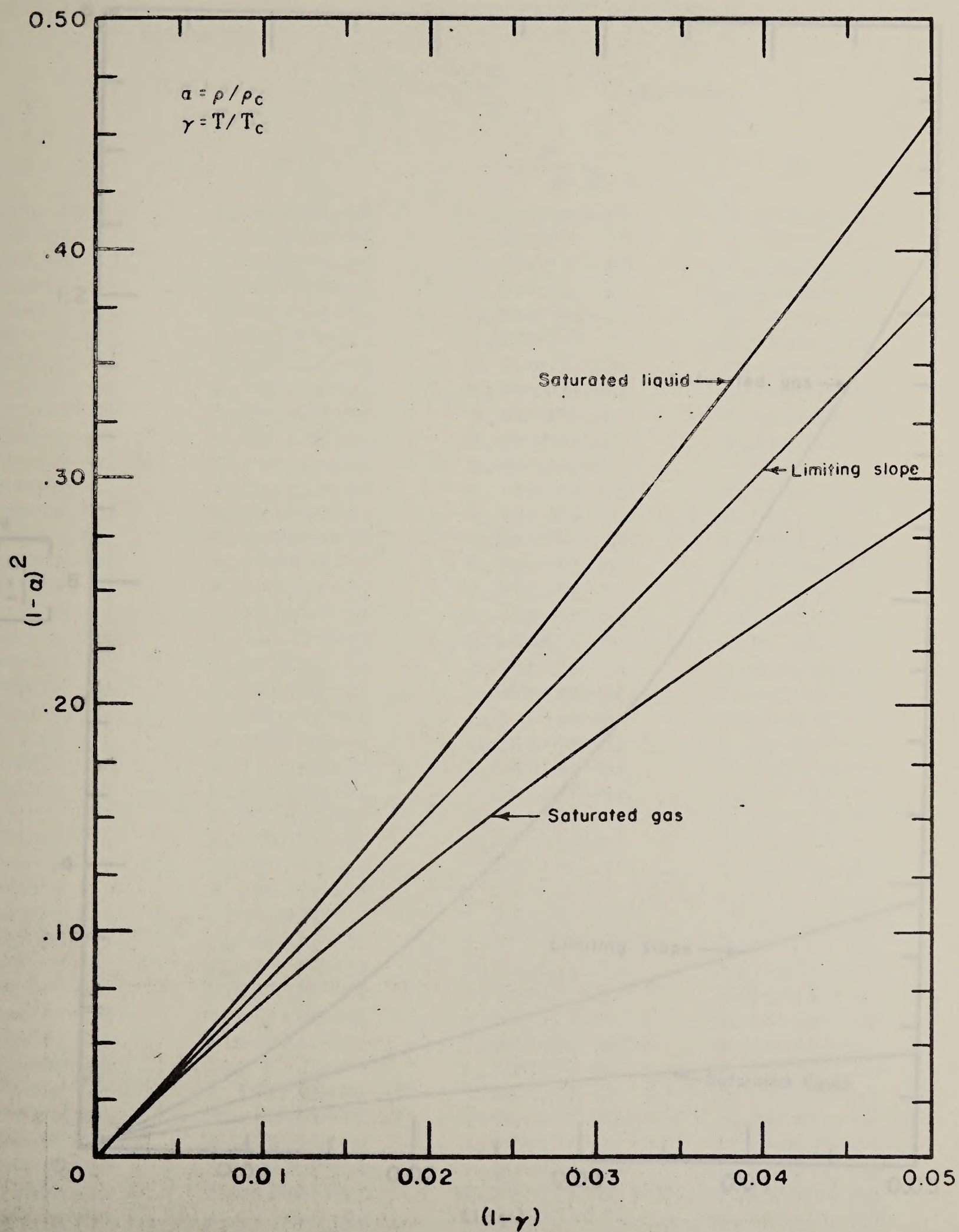


FIGURE 7. — Redlich-Kwong Fluid, Density-Coexistence Data as a Function of Temperature Near the Critical Point.

TABLE 5.1.6

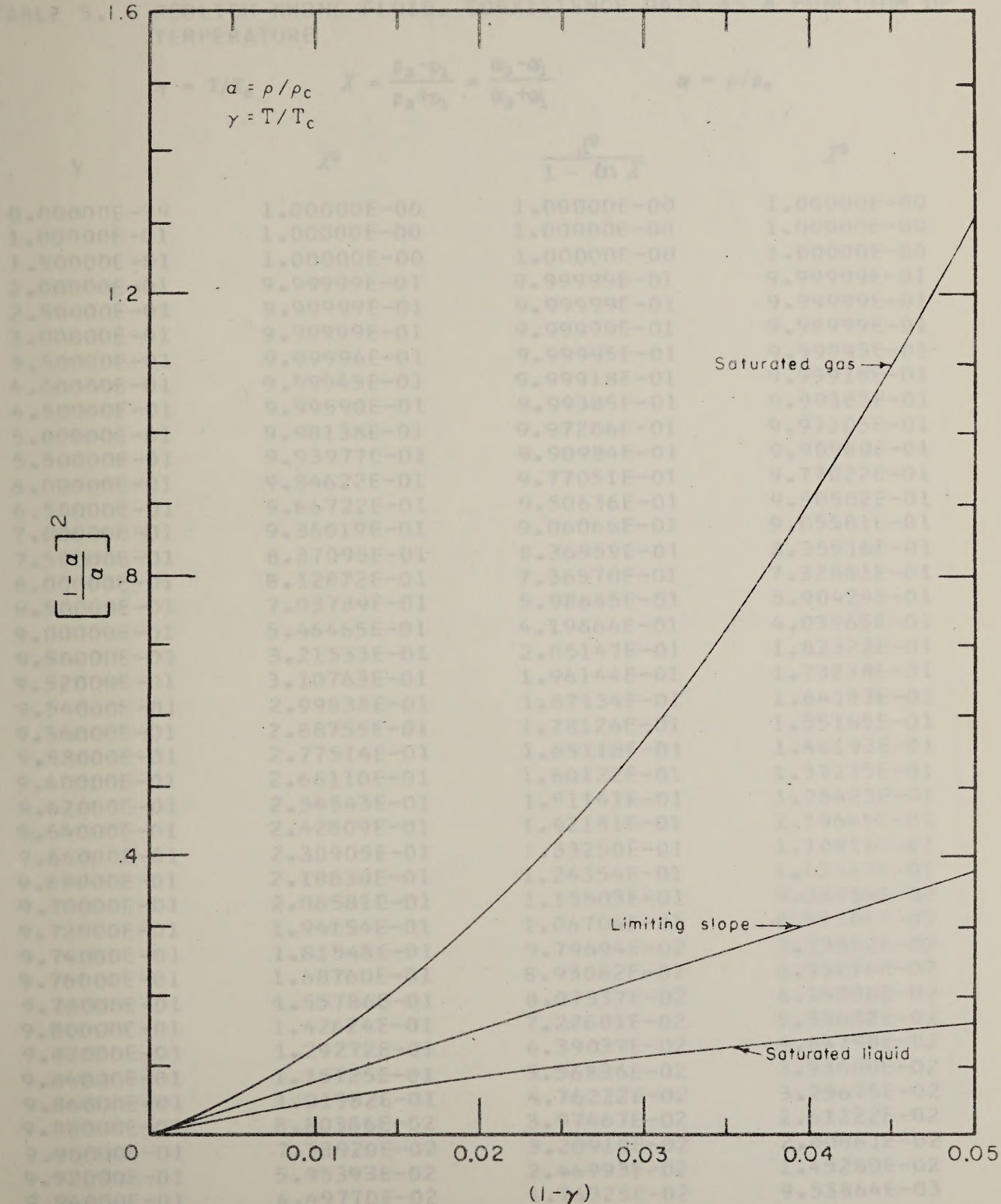


FIGURE 8.- Redlich-Kwong Fluid, Volume-Coexistence Data as a Function of Temperature Near the Critical Point.

TABLE 5. - REDLICH-KWONG FLUID, COEXISTENCE DATA AS A FUNCTION OF TEMPERATURE

$$\gamma = T/T_c \quad X = \frac{\rho_3 - \rho_1}{\rho_3 + \rho_1} = \frac{\alpha_3 - \alpha_1}{\alpha_3 + \alpha_1} \quad \alpha = \rho/\rho_c$$

γ	X^2	$\frac{X^2}{1 - \ln X}$	X^3
0.00000E-99	1.00000E-00	1.00000E-00	1.00000E-00
1.00000E-01	1.00000E-00	1.00000E-00	1.00000E-00
1.50000E-01	1.00000E-00	1.00000E-00	1.00000E-00
2.00000E-01	9.99999E-01	9.99999E-01	9.99999E-01
2.50000E-01	9.99999E-01	9.99999E-01	9.99999E-01
3.00000E-01	9.99999E-01	9.99999E-01	9.99999E-01
3.50000E-01	9.99996E-01	9.99995E-01	9.99995E-01
4.00000E-01	9.99945E-01	9.99918E-01	9.99918E-01
4.50000E-01	9.99590E-01	9.99385E-01	9.99385E-01
5.00000E-01	9.98136E-01	9.97206E-01	9.97205E-01
5.50000E-01	9.93977E-01	9.90984E-01	9.90980E-01
6.00000E-01	9.84622E-01	9.77051E-01	9.77022E-01
6.50000E-01	9.66722E-01	9.50636E-01	9.50502E-01
7.00000E-01	9.36019E-01	9.06066E-01	9.05581E-01
7.50000E-01	8.87095E-01	8.36959E-01	8.35516E-01
8.00000E-01	8.12872E-01	7.36570E-01	7.32881E-01
8.50000E-01	7.03789E-01	5.98645E-01	5.90424E-01
9.00000E-01	5.46465E-01	4.19666E-01	4.03965E-01
9.50000E-01	3.21533E-01	2.05147E-01	1.82322E-01
9.52000E-01	3.10763E-01	1.96144E-01	1.73238E-01
9.54000E-01	2.99838E-01	1.87134E-01	1.64183E-01
9.56000E-01	2.88755E-01	1.78124E-01	1.55165E-01
9.58000E-01	2.77514E-01	1.69118E-01	1.46193E-01
9.60000E-01	2.66110E-01	1.60122E-01	1.37275E-01
9.62000E-01	2.54543E-01	1.51141E-01	1.28423E-01
9.64000E-01	2.42809E-01	1.42181E-01	1.19645E-01
9.66000E-01	2.30905E-01	1.33250E-01	1.10956E-01
9.68000E-01	2.18830E-01	1.24354E-01	1.02367E-01
9.70000E-01	2.06581E-01	1.15503E-01	9.38936E-02
9.72000E-01	1.94154E-01	1.06704E-01	8.55504E-02
9.74000E-01	1.81548E-01	9.79694E-02	7.73552E-02
9.76000E-01	1.68760E-01	8.93082E-02	6.93274E-02
9.78000E-01	1.55786E-01	8.07337E-02	6.14886E-02
9.80000E-01	1.42624E-01	7.22601E-02	5.38632E-02
9.82000E-01	1.29272E-01	6.39037E-02	4.64790E-02
9.84000E-01	1.15725E-01	5.56836E-02	3.93680E-02
9.86000E-01	1.01982E-01	4.76222E-02	3.25675E-02
9.88000E-01	8.80386E-02	3.97467E-02	2.61222E-02
9.90000E-01	7.38920E-02	3.20910E-02	2.00861E-02
9.92000E-01	5.95393E-02	2.46993E-02	1.45280E-02
9.94000E-01	4.49770E-02	1.76325E-02	9.53864E-03
9.96000E-01	3.02019E-02	1.09828E-02	5.24872E-03
9.98000E-01	1.52107E-02	4.91800E-03	1.87597E-03
9.99000E-01	7.63305E-03	2.22043E-03	6.66879E-04
1.00000E-00	0.00000E-99	0.00000E-99	0.00000E-99

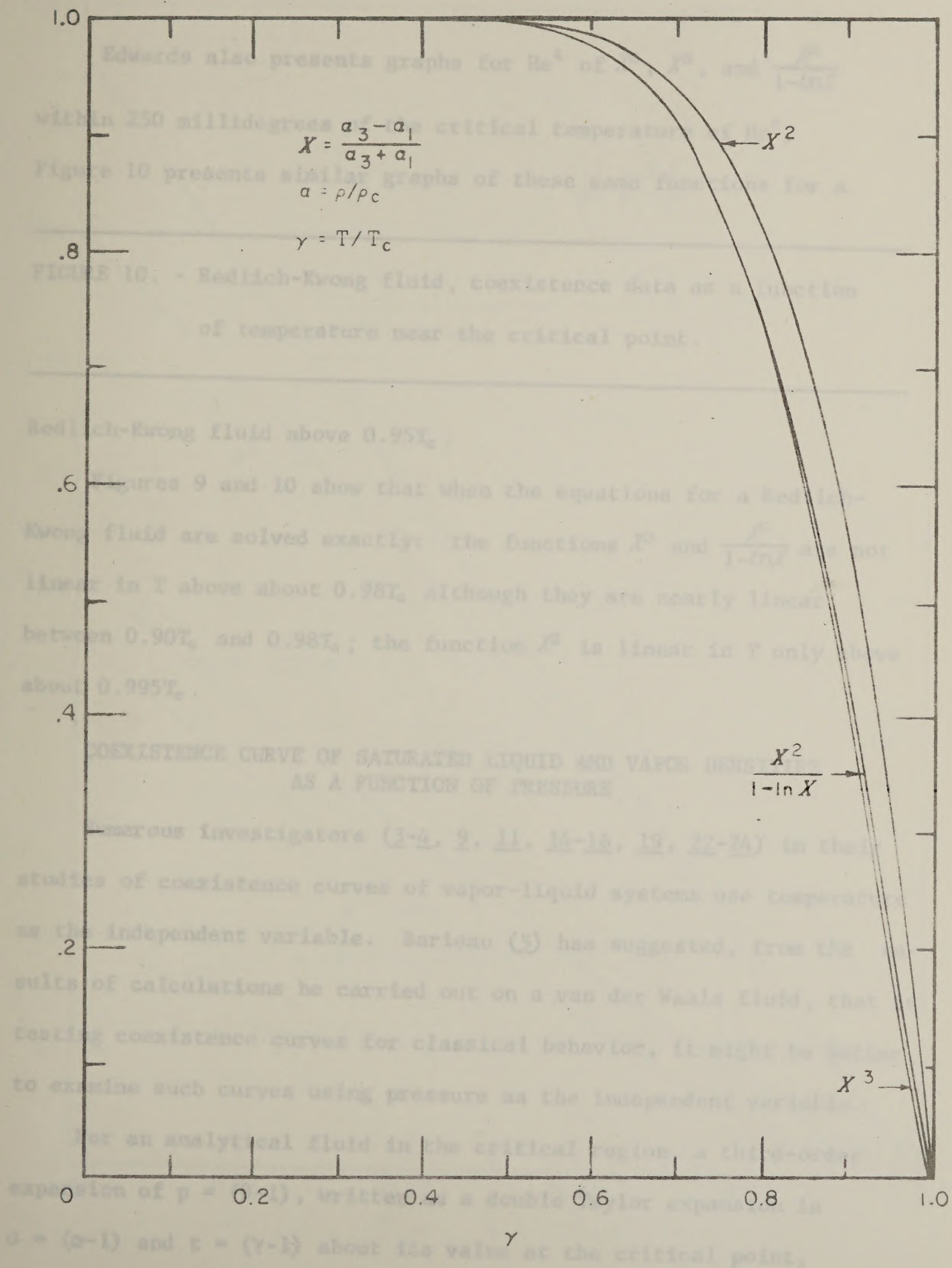


FIGURE 9. - Redlich-Kwong Fluid, Coexistence Data as a Function of Temperature.

Edwards also presents graphs for He^4 of X^2 , X^3 , and $\frac{X^2}{1-\ln X}$ within 250 millidegrees of the critical temperature of He^4 .

Figure 10 presents similar graphs of these same functions for a

FIGURE 10. - Redlich-Kwong fluid, coexistence data as a function of temperature near the critical point.

Redlich-Kwong fluid above $0.95T_c$.

Figures 9 and 10 show that when the equations for a Redlich-Kwong fluid are solved exactly: the functions X^3 and $\frac{X^2}{1-\ln X}$ are not linear in T above about $0.98T_c$ although they are nearly linear between $0.90T_c$ and $0.98T_c$; the function X^2 is linear in T only above about $0.995T_c$.

COEXISTENCE CURVE OF SATURATED LIQUID AND VAPOR DENSITIES AS A FUNCTION OF PRESSURE

Numerous investigators (3-4, 9, 11, 14-16, 19, 22-24) in their studies of coexistence curves of vapor-liquid systems use temperature as the independent variable. Barieau (5) has suggested, from the results of calculations he carried out on a van der Waals fluid, that in testing coexistence curves for classical behavior, it might be better to examine such curves using pressure as the independent variable.

For an analytical fluid in the critical region, a third-order expansion of $p = (\beta-1)$, written as a double Taylor expansion in $a = (\alpha-1)$ and $t = (\gamma-1)$ about its value at the critical point,

FIGURE 10. - Redlich-Kwong Fluid, Coexistence Data, as a Function of Temperature Near the Critical Point

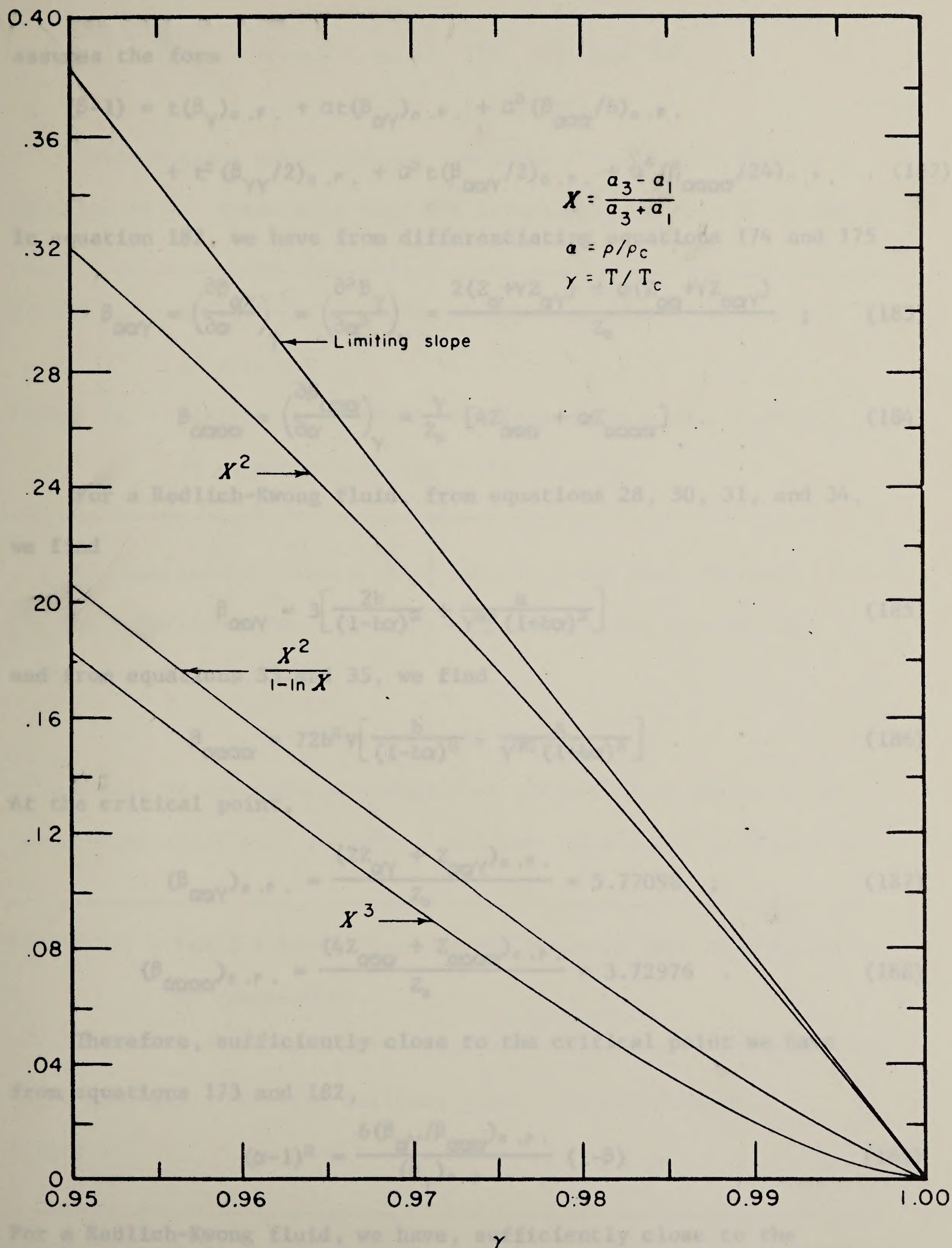


FIGURE 10.—Redlich-Kwong Fluid, Coexistence Data as a Function of Temperature Near the Critical Point.

assumes the form

$$(\beta-1) = t(\beta_Y)_{c.p.} + \alpha t(\beta_{\alpha Y})_{c.p.} + \alpha^3 (\beta_{\alpha\alpha\alpha}/6)_{c.p.} \\ + t^2 (\beta_{YY}/2)_{c.p.} + \alpha^2 t(\beta_{\alpha\alpha Y}/2)_{c.p.} + \alpha^4 (\beta_{\alpha\alpha\alpha\alpha}/24)_{c.p.} \quad (182)$$

In equation 182, we have from differentiating equations 174 and 175

$$\beta_{\alpha\alpha Y} = \left(\frac{\partial \beta_{\alpha Y}}{\partial \alpha} \right)_Y = \left(\frac{\partial^2 \beta_Y}{\partial \alpha^2} \right)_Y = \frac{2(Z_{\alpha} + YZ_{\alpha Y}) + \alpha(Z_{\alpha\alpha} + YZ_{\alpha\alpha Y})}{Z_c} ; \quad (183)$$

$$\beta_{\alpha\alpha\alpha\alpha} = \left(\frac{\partial \beta_{\alpha\alpha\alpha}}{\partial \alpha} \right)_Y = \frac{Y}{Z_c} [4Z_{\alpha\alpha\alpha} + \alpha Z_{\alpha\alpha\alpha\alpha}] \quad (184)$$

For a Redlich-Kwong fluid, from equations 28, 30, 31, and 34,

we find

$$\beta_{\alpha\alpha Y} = 3 \left[\frac{2b}{(1-b\alpha)^3} + \frac{a}{Y^{3/2}(1+b\alpha)^3} \right] \quad (185)$$

and from equations 33 and 35, we find

$$\beta_{\alpha\alpha\alpha\alpha} = 72b^2 Y \left[\frac{b}{(1-b\alpha)^5} - \frac{a}{Y^{3/2}(1+b\alpha)^5} \right] \quad (186)$$

At the critical point,

$$(\beta_{\alpha\alpha Y})_{c.p.} = \frac{(2Z_{\alpha Y} + Z_{\alpha\alpha Y})_{c.p.}}{Z_c} = 5.77098 ; \quad (187)$$

$$(\beta_{\alpha\alpha\alpha\alpha})_{c.p.} = \frac{(4Z_{\alpha\alpha\alpha} + Z_{\alpha\alpha\alpha\alpha})_{c.p.}}{Z_c} = 3.72976 \quad (188)$$

Therefore, sufficiently close to the critical point we have from equations 173 and 182,

$$(\alpha-1)^2 = \frac{6(\beta_{\alpha Y}/\beta_{\alpha\alpha\alpha\alpha})_{c.p.}}{(\beta_Y)_{c.p.}} (1-\beta) \quad (189)$$

For a Redlich-Kwong fluid, we have, sufficiently close to the

critical point, from equations 51, 178, 179, and 189,

$$(\alpha-1)^2 = 1.372808(1-\beta) \quad . \quad (190)$$

Table 6 gives values of the functions X^2 , X^3 , and $\frac{X^2}{1-\ln X}$ as a function of β . These same data are illustrated in figures 11 and 12.

FIGURE 11. - Redlich-Kwong fluid, coexistence data as a function of pressure.

FIGURE 12. - Redlich-Kwong fluid, coexistence data as a function of pressure near the critical point.

A comparison of figures 9-12 clearly shows that the function X^2 , for a Redlich-Kwong fluid, is more linear when plotted as a function of β rather than γ .

VAPOR PRESSURE CURVE

Values of the reduced pressure as a function of the reduced temperature are listed in table 7 and are illustrated in figure 13.

FIGURE 13. - Redlich-Kwong fluid, vapor pressure data as a function of temperature.

These same data, near the critical point, are illustrated in figure 14.

FIGURE 14. - Redlich-Kwong fluid, vapor pressure data as a function of temperature near the critical point.

TABLE 6. - REDLICH-KWONG FLUID, COEXISTENCE DATA AS A FUNCTION OF PRESSURE

$$\beta = P/P_c \quad X = \frac{\rho_3 - \rho_1}{\rho_3 + \rho_1} = \frac{\alpha_3 - \alpha_1}{\alpha_3 + \alpha_1} \quad \alpha = \rho/\rho_c$$

β	X^2	$\frac{X^2}{1 - \ln X}$	X^3
0.000000E-99	1.000000E-00	1.000000E-00	1.000000E-00
9.59064E-46	1.000000E-00	1.000000E-00	1.000000E-00
1.95995E-24	1.000000E-00	1.000000E-00	1.000000E-00
1.53449E-15	9.99999E-01	9.99999E-01	9.99999E-01
7.18061E-11	9.99999E-01	9.99999E-01	9.99999E-01
4.50798E-08	9.99999E-01	9.99999E-01	9.99999E-01
3.02123E-06	9.99996E-01	9.99995E-01	9.99995E-01
5.57479E-05	9.99945E-01	9.99918E-01	9.99918E-01
4.61534E-04	9.99590E-01	9.99385E-01	9.99385E-01
2.25834E-03	9.98136E-01	9.97206E-01	9.97205E-01
7.71655E-03	9.93977E-01	9.90984E-01	9.90980E-01
2.04768E-02	9.84622E-01	9.77051E-01	9.77022E-01
4.52692E-02	9.66722E-01	9.50636E-01	9.50502E-01
8.74419E-02	9.36019E-01	9.06066E-01	9.05581E-01
1.52527E-01	8.87095E-01	8.36959E-01	8.35516E-01
2.45938E-01	8.12872E-01	7.36570E-01	7.32881E-01
3.72802E-01	7.03789E-01	5.98645E-01	5.90424E-01
5.37888E-01	5.46465E-01	4.19666E-01	4.03965E-01
7.45600E-01	3.21533E-01	2.05147E-01	1.82322E-01
7.54853E-01	3.10763E-01	1.96144E-01	1.73238E-01
7.64182E-01	2.99838E-01	1.87134E-01	1.64183E-01
7.73586E-01	2.88755E-01	1.78124E-01	1.55165E-01
7.83065E-01	2.77514E-01	1.69118E-01	1.46193E-01
7.92620E-01	2.66110E-01	1.60122E-01	1.37275E-01
8.02251E-01	2.54543E-01	1.51141E-01	1.28423E-01
8.11958E-01	2.42809E-01	1.42181E-01	1.19645E-01
8.21742E-01	2.30905E-01	1.33250E-01	1.10956E-01
8.31602E-01	2.18830E-01	1.24354E-01	1.02367E-01
8.41540E-01	2.06581E-01	1.15503E-01	9.38936E-02
8.51555E-01	1.94154E-01	1.06704E-01	8.55504E-02
8.61647E-01	1.81548E-01	9.79694E-02	7.73552E-02
8.71816E-01	1.68760E-01	8.93082E-02	6.93274E-02
8.82064E-01	1.55786E-01	8.07337E-02	6.14886E-02
8.92390E-01	1.42624E-01	7.22601E-02	5.38632E-02
9.02794E-01	1.29272E-01	6.39037E-02	4.64790E-02
9.13277E-01	1.15725E-01	5.56836E-02	3.93680E-02
9.23839E-01	1.01982E-01	4.76222E-02	3.25675E-02
9.34480E-01	8.80386E-02	3.97467E-02	2.61222E-02
9.45200E-01	7.38920E-02	3.20910E-02	2.00861E-02
9.56000E-01	5.95393E-02	2.46993E-02	1.45280E-02
9.66879E-01	4.49770E-02	1.76325E-02	9.53864E-03
9.77839E-01	3.02019E-02	1.09828E-02	5.24872E-03
9.88879E-01	1.52107E-02	4.91800E-03	1.87597E-03
9.94429E-01	7.63305E-03	2.22043E-03	6.66879E-04
1.00000E-00	0.00000E-99	0.00000E-99	0.00000E-99

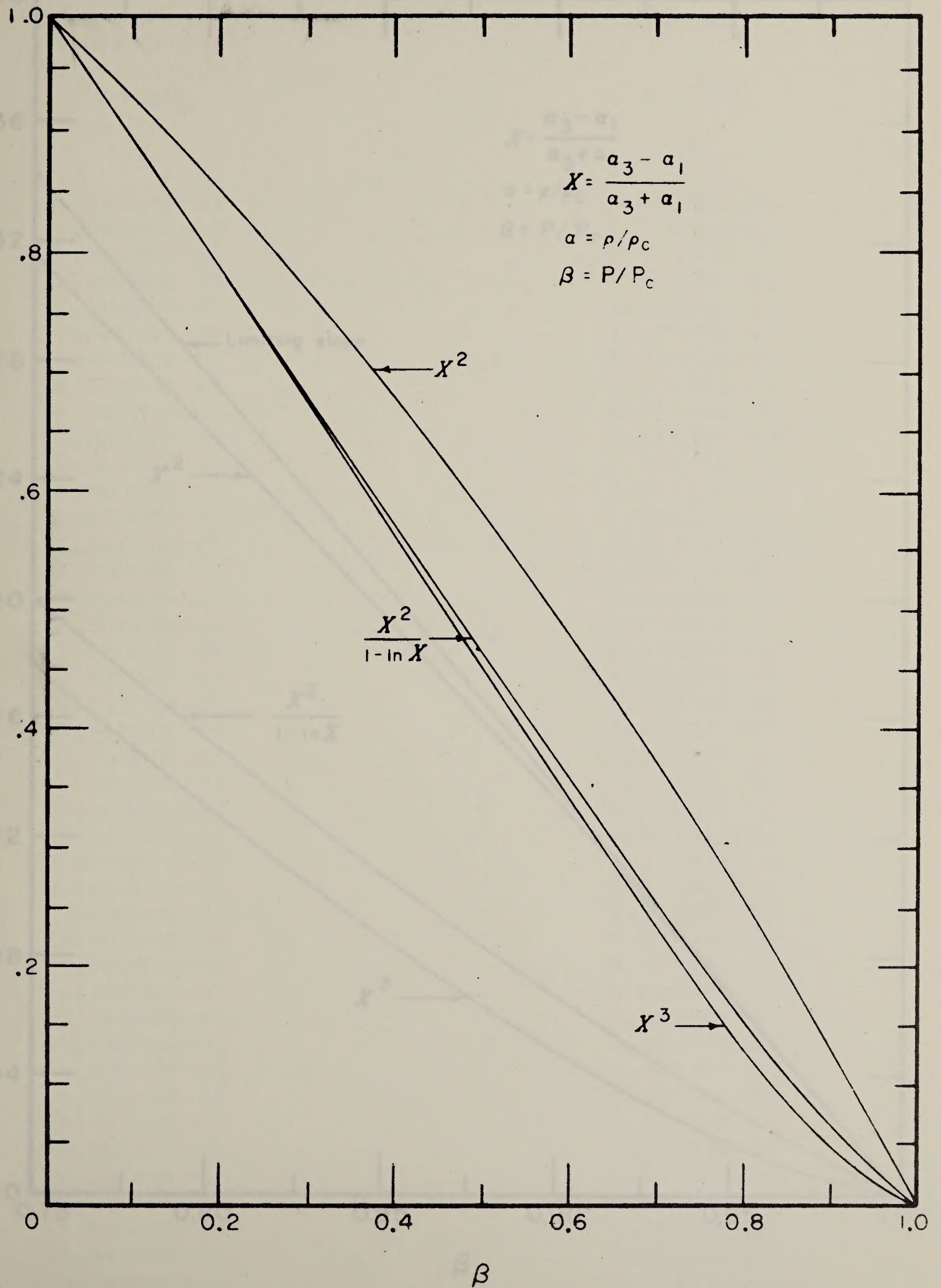


FIGURE II. - Redlich-Kwong Fluid, Coexistence Data as a Function of Pressure.

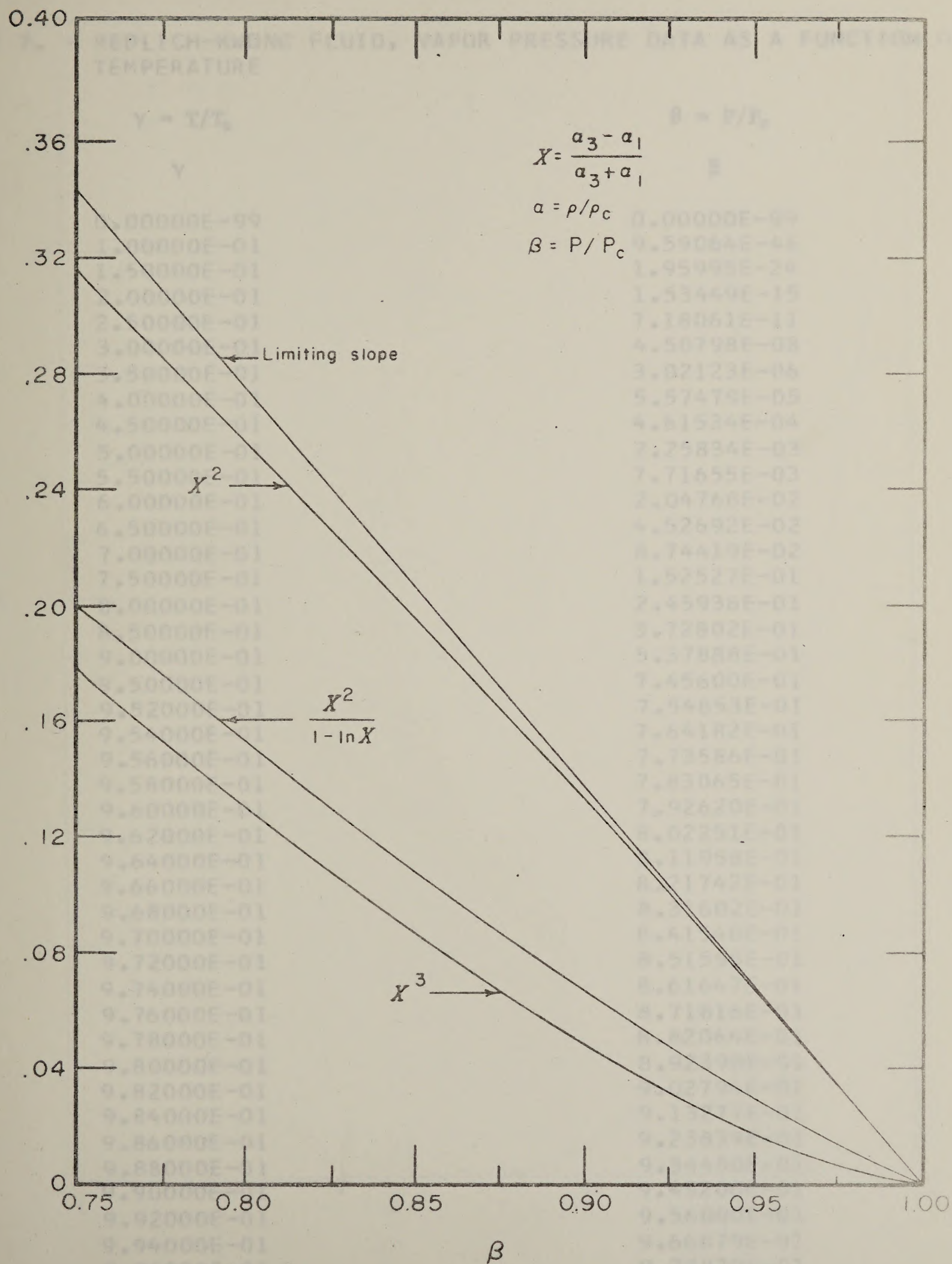


FIGURE 12. - Redlich - Kwong Fluid, Coexistence Data as a Function of Pressure Near the Critical Point.

TABLE 7. - REDLICH-KWONG FLUID, VAPOR PRESSURE DATA AS A FUNCTION OF TEMPERATURE

$\gamma = T/T_c$	$\beta = P/P_c$
γ	β
0.00000E-99	0.00000E-99
1.00000E-01	9.59064E-46
1.50000E-01	1.95995E-24
2.00000E-01	1.53449E-15
2.50000E-01	7.18061E-11
3.00000E-01	4.50798E-08
3.50000E-01	3.02123E-06
4.00000E-01	5.57479E-05
4.50000E-01	4.61534E-04
5.00000E-01	2.25834E-03
5.50000E-01	7.71655E-03
6.00000E-01	2.04768E-02
6.50000E-01	4.52692E-02
7.00000E-01	8.74419E-02
7.50000E-01	1.52527E-01
8.00000E-01	2.45938E-01
8.50000E-01	3.72802E-01
9.00000E-01	5.37888E-01
9.50000E-01	7.45600E-01
9.52000E-01	7.54853E-01
9.54000E-01	7.64182E-01
9.56000E-01	7.73586E-01
9.58000E-01	7.83065E-01
9.60000E-01	7.92620E-01
9.62000E-01	8.02251E-01
9.64000E-01	8.11958E-01
9.66000E-01	8.21742E-01
9.68000E-01	8.31602E-01
9.70000E-01	8.41540E-01
9.72000E-01	8.51555E-01
9.74000E-01	8.61647E-01
9.76000E-01	8.71816E-01
9.78000E-01	8.82064E-01
9.80000E-01	8.92390E-01
9.82000E-01	9.02794E-01
9.84000E-01	9.13277E-01
9.86000E-01	9.23839E-01
9.88000E-01	9.34480E-01
9.90000E-01	9.45200E-01
9.92000E-01	9.56000E-01
9.94000E-01	9.66879E-01
9.96000E-01	9.77839E-01
9.98000E-01	9.88879E-01
9.99000E-01	9.94429E-01
1.00000E-00	1.00000E-00

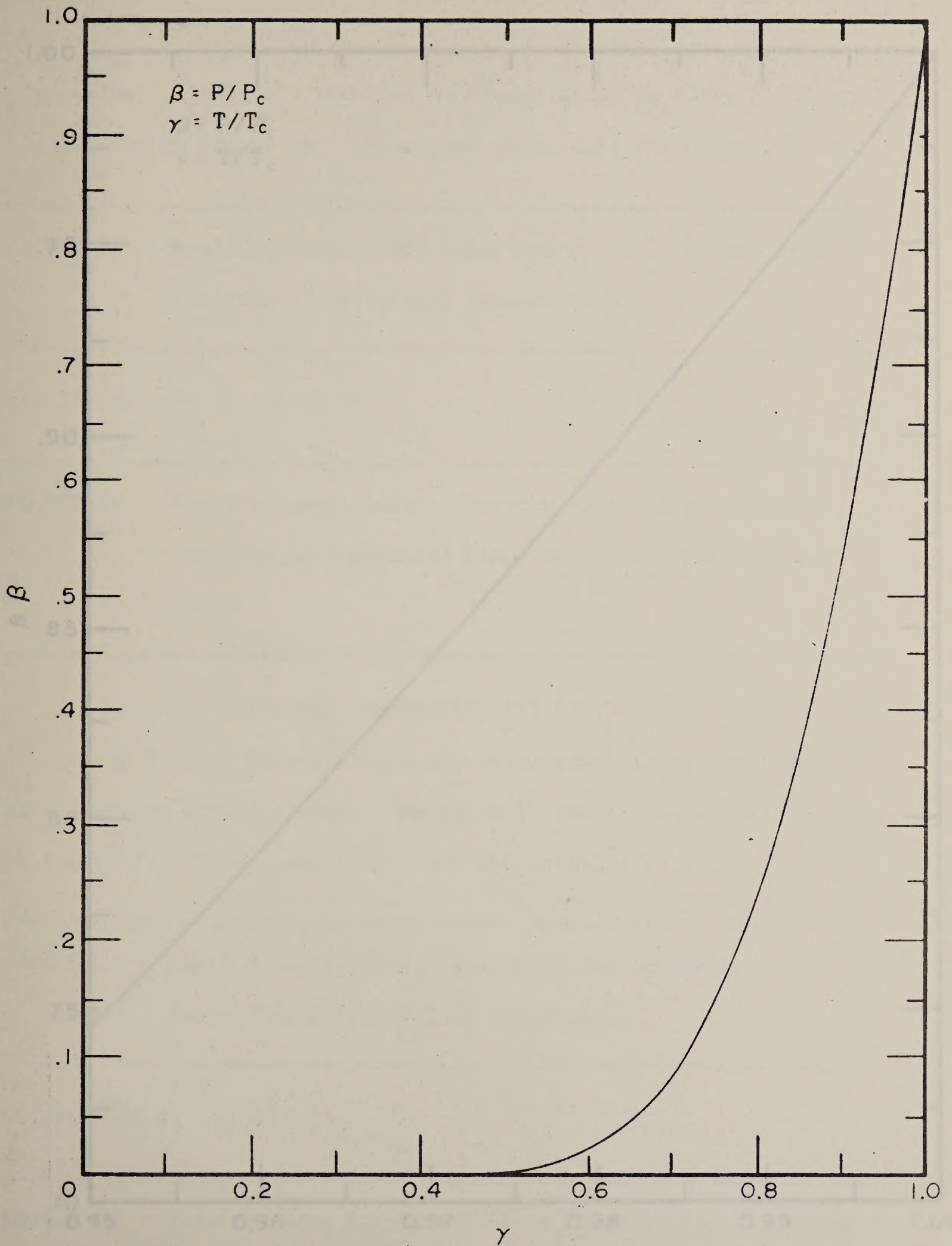


FIGURE 13. - Redlich-Kwong Fluid, Vapor Pressure Data as a Function of Temperature.

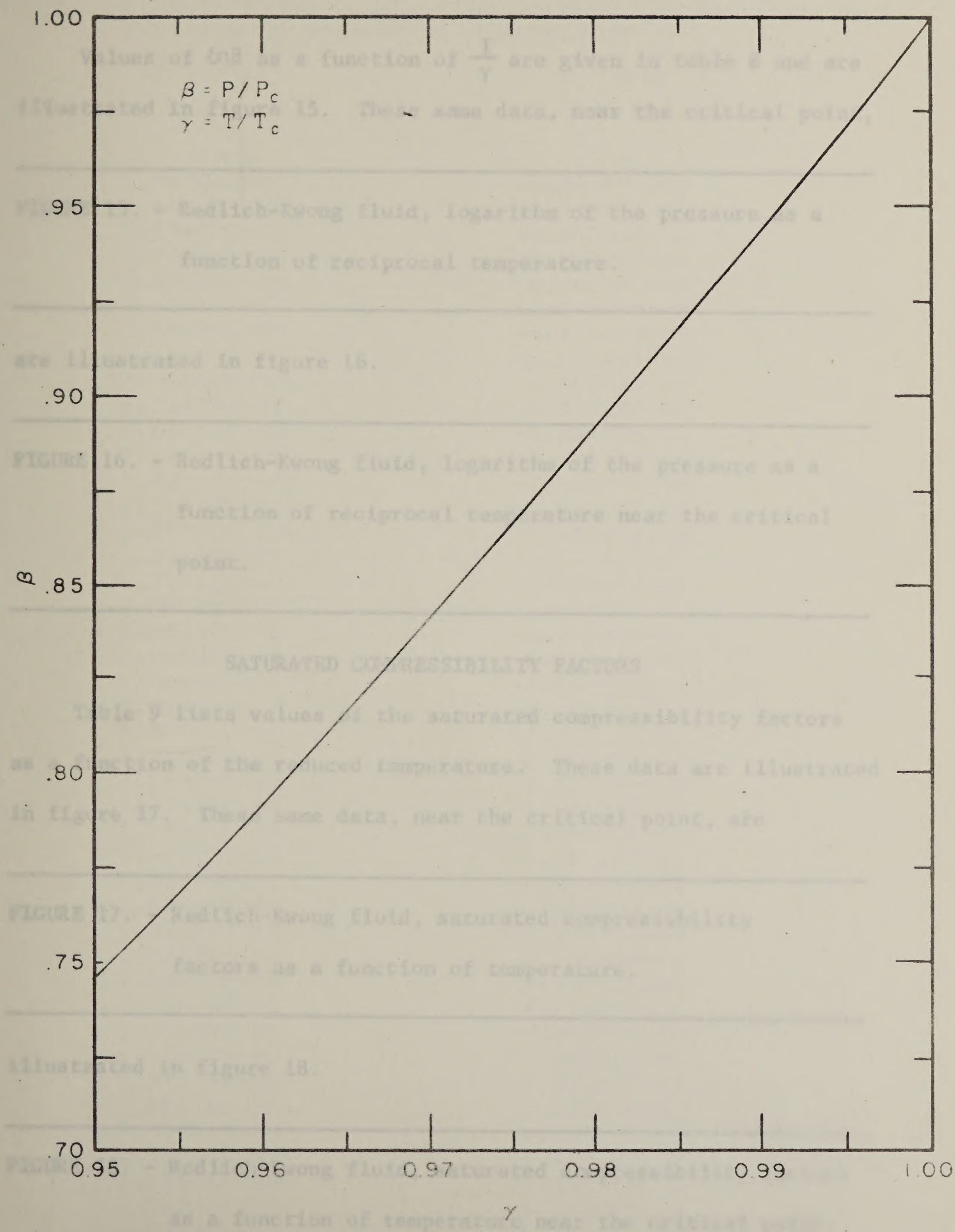
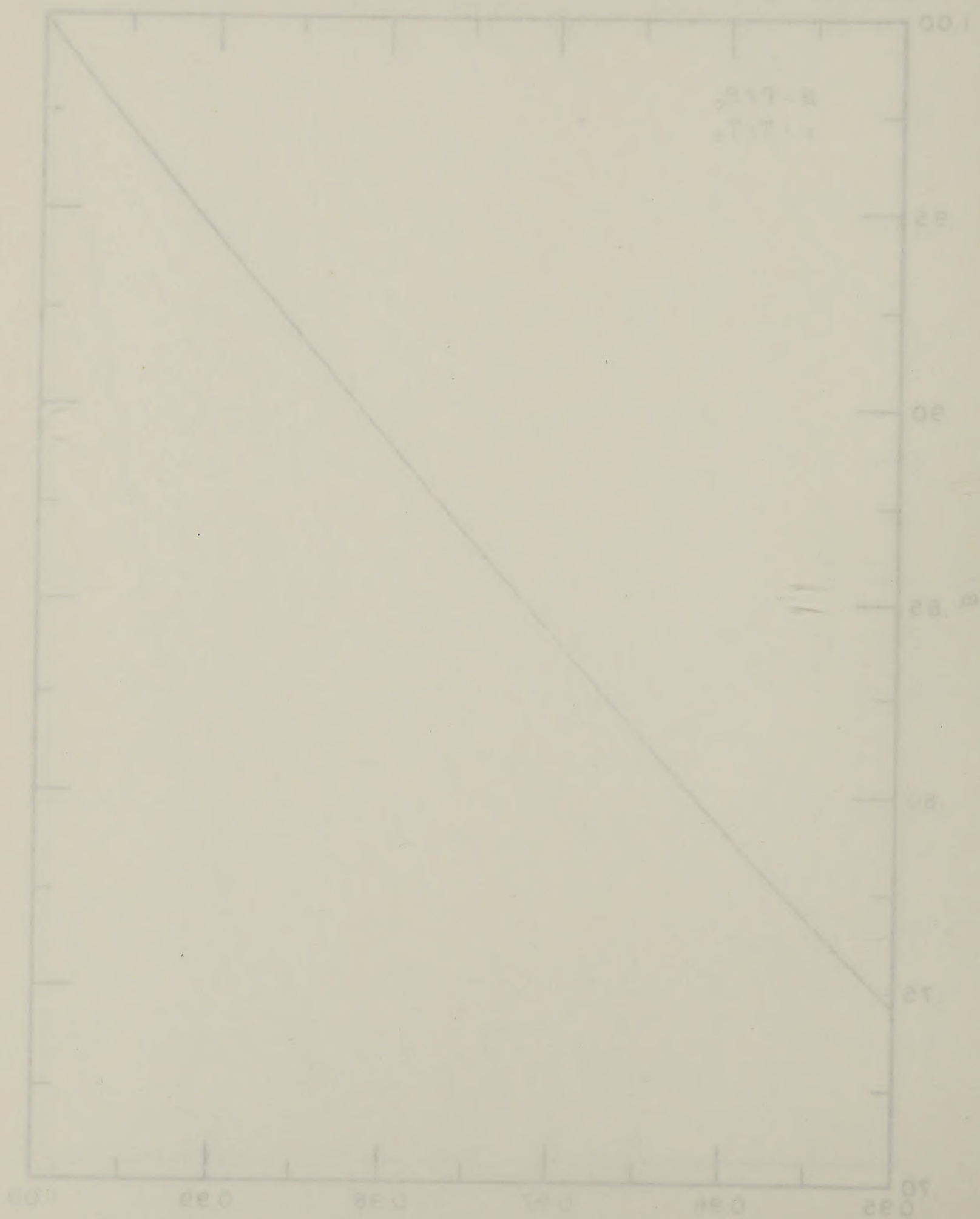


FIGURE 14. - Redlich-Kwong Fluid, Vapor Pressure Data as a Function of Temperature Near the Critical Point.

FIGURE 1A - Redlich-Kwong Fluid Vapor Pressure Data as a Function of Temperature Near the Critical Point



Values of $\ln \beta$ as a function of $\frac{1}{T}$ are given in table 8 and are illustrated in figure 15. These same data, near the critical point,

FIGURE 15. - Redlich-Kwong fluid, logarithm of the pressure as a function of reciprocal temperature.

are illustrated in figure 16.

FIGURE 16. - Redlich-Kwong fluid, logarithm of the pressure as a function of reciprocal temperature near the critical point.

SATURATED COMPRESSIBILITY FACTORS

Table 9 lists values of the saturated compressibility factors as a function of the reduced temperature. These data are illustrated in figure 17. These same data, near the critical point, are

FIGURE 17. - Redlich-Kwong fluid, saturated compressibility factors as a function of temperature.

illustrated in figure 18.

FIGURE 18. - Redlich-Kwong fluid, saturated compressibility factors as a function of temperature near the critical point.

TABLE 8. - REDLICH-KWONG FLUID, LOGARITHM OF THE PRESSURE AS A FUNCTION OF RECIPROCAL TEMPERATURE

$\gamma = T/T_c$	$\beta = P/P_c$
$1/\gamma$	$\ln \beta$
$+\infty$	$-\infty$
1.00000E+01	-1.03658E+02
6.66666E-00	-5.45891E+01
5.00000E-00	-3.41105E+01
4.00000E-00	-2.33570E+01
3.33333E-00	-1.69148E+01
2.85714E-00	-1.27098E+01
2.50000E-00	-9.79467E-00
2.22222E-00	-7.68095E-00
2.00000E-00	-6.09312E-00
1.81818E-00	-4.86438E-00
1.66666E-00	-3.88845E-00
1.53846E-00	-3.09512E-00
1.42857E-00	-2.43677E-00
1.33333E-00	-1.88041E-00
1.25000E-00	-1.40267E-00
1.17647E-00	-9.86707E-01
1.11111E-00	-6.20104E-01
1.05263E-00	-2.93566E-01
1.05042E-00	-2.81231E-01
1.04821E-00	-2.68949E-01
1.04602E-00	-2.56718E-01
1.04384E-00	-2.44539E-01
1.04166E-00	-2.32410E-01
1.03950E-00	-2.20333E-01
1.03734E-00	-2.08305E-01
1.03519E-00	-1.96328E-01
1.03305E-00	-1.84400E-01
1.03092E-00	-1.72521E-01
1.02880E-00	-1.60691E-01
1.02669E-00	-1.48909E-01
1.02459E-00	-1.37175E-01
1.02249E-00	-1.25490E-01
1.02040E-00	-1.13851E-01
1.01832E-00	-1.02260E-01
1.01626E-00	-9.07155E-02
1.01419E-00	-7.92172E-02
1.01214E-00	-6.77649E-02
1.01010E-00	-5.63584E-02
1.00806E-00	-4.49972E-02
1.00603E-00	-3.36811E-02
1.00401E-00	-2.24097E-02
1.00200E-00	-1.11828E-02
1.00100E-00	-5.58591E-03
1.00000E-00	0.00000E-99

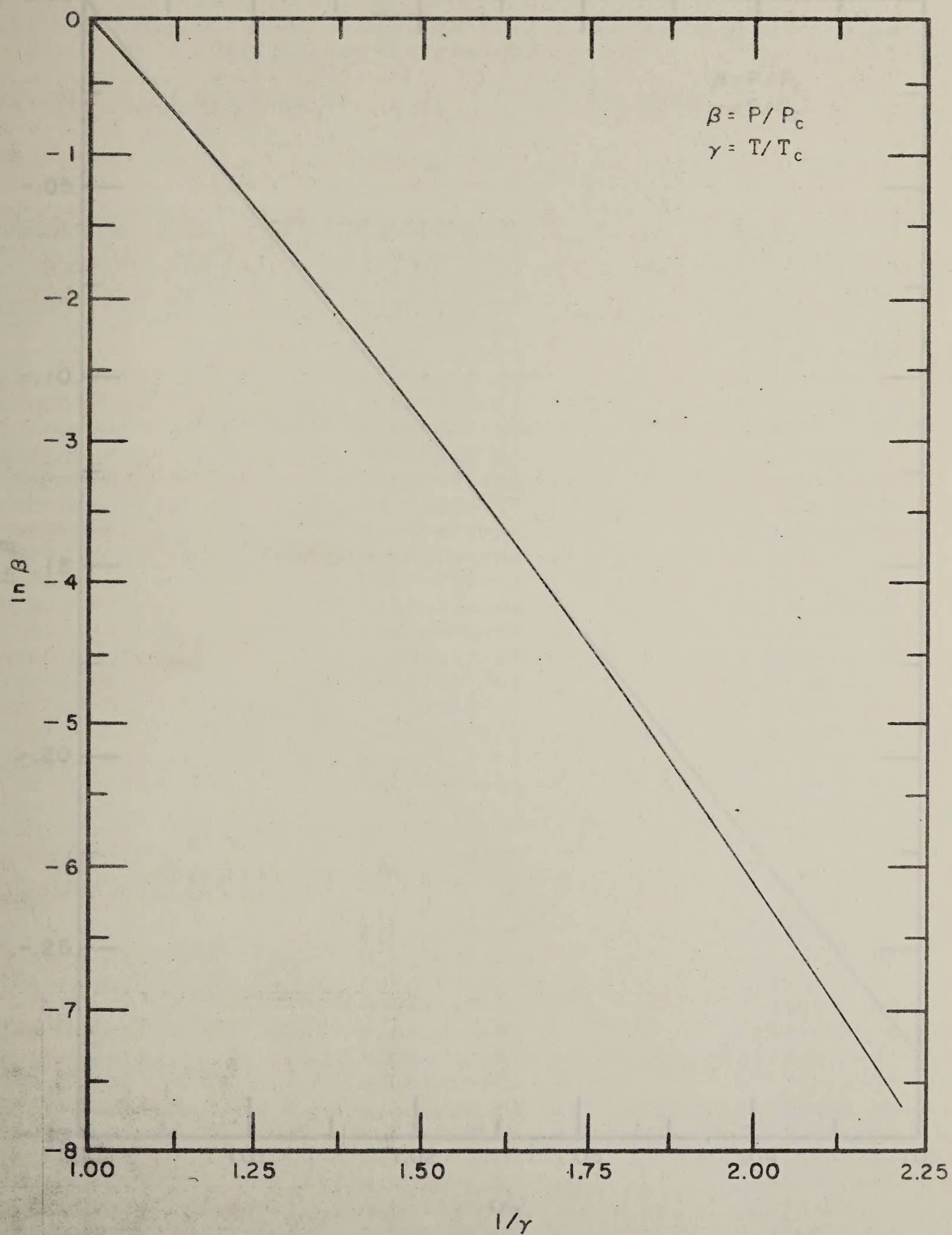


FIGURE 15.- Redlich-Kwong Fluid, Logarithm of the Pressure as a Function of Reciprocal Temperature.

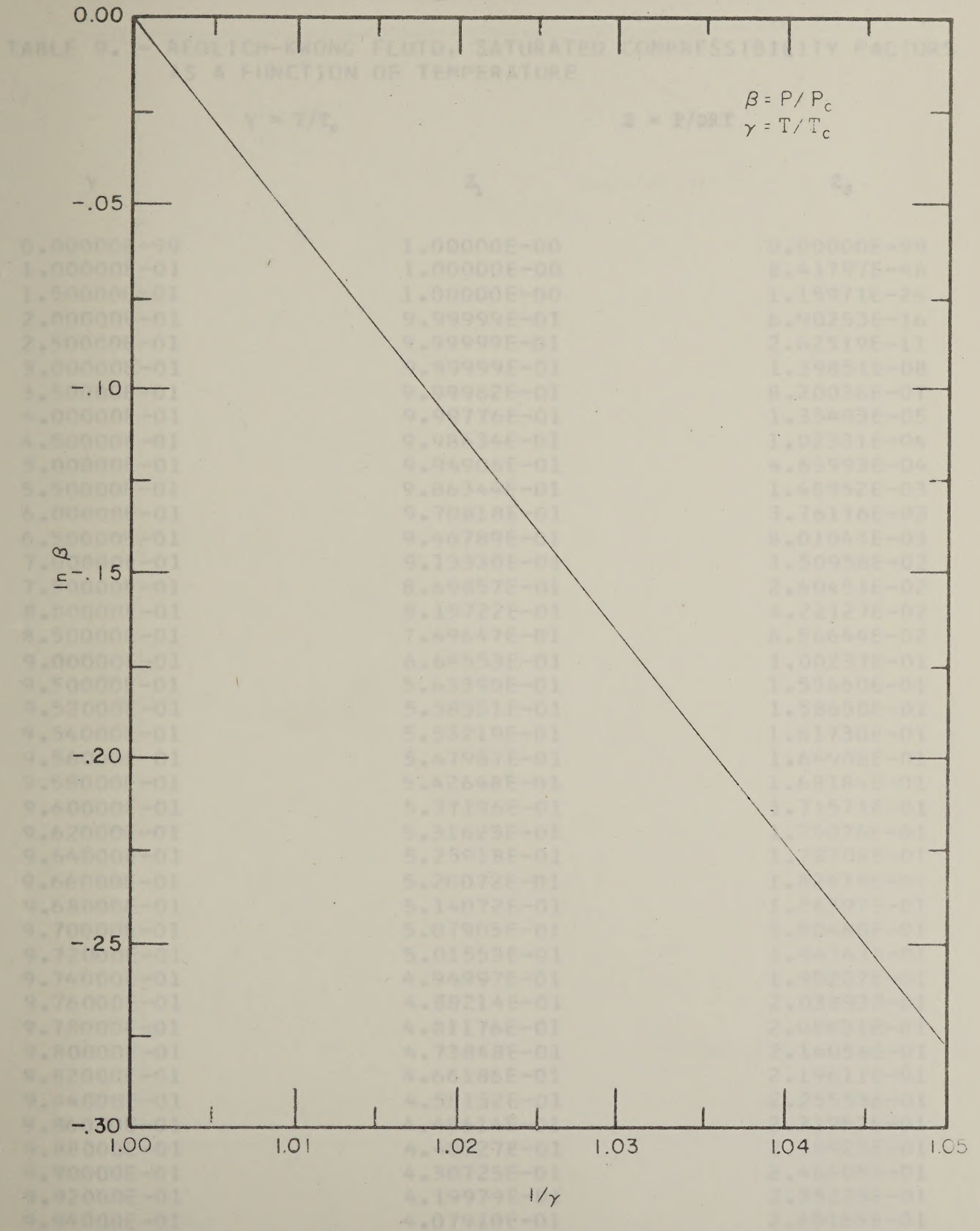


FIGURE 16. - Redlich - Kwong Fluid, Logarithm of the Pressure as a Function of Reciprocal Temperature Near the Critical Point.

TABLE 9. - REDLICH-KWONG FLUID, SATURATED COMPRESSIBILITY FACTORS
AS A FUNCTION OF TEMPERATURE

$\gamma = T/T_c$	Z_1	Z_3
0.00000E-99	1.00000E-00	0.00000E-99
1.00000E-01	1.00000E-00	8.41797E-46
1.50000E-01	1.00000E-00	1.15971E-24
2.00000E-01	9.99999E-01	6.90253E-16
2.50000E-01	9.99999E-01	2.62519E-11
3.00000E-01	9.99999E-01	1.39851E-08
3.50000E-01	9.99982E-01	8.20036E-07
4.00000E-01	9.99776E-01	1.35493E-05
4.50000E-01	9.98634E-01	1.02331E-04
5.00000E-01	9.94906E-01	4.63993E-04
5.50000E-01	9.86344E-01	1.48952E-03
6.00000E-01	9.70818E-01	3.76116E-03
6.50000E-01	9.46789E-01	8.01043E-03
7.00000E-01	9.13330E-01	1.50956E-02
7.50000E-01	8.69857E-01	2.60451E-02
8.00000E-01	8.15722E-01	4.22127E-02
8.50000E-01	7.49647E-01	6.56644E-02
9.00000E-01	6.68553E-01	1.00237E-01
9.50000E-01	5.63390E-01	1.55660E-01
9.52000E-01	5.58351E-01	1.58650E-01
9.54000E-01	5.53219E-01	1.61730E-01
9.56000E-01	5.47987E-01	1.64906E-01
9.58000E-01	5.42648E-01	1.68184E-01
9.60000E-01	5.37196E-01	1.71571E-01
9.62000E-01	5.31623E-01	1.75076E-01
9.64000E-01	5.25918E-01	1.78708E-01
9.66000E-01	5.20072E-01	1.82478E-01
9.68000E-01	5.14072E-01	1.86397E-01
9.70000E-01	5.07905E-01	1.90480E-01
9.72000E-01	5.01553E-01	1.94743E-01
9.74000E-01	4.94997E-01	1.99207E-01
9.76000E-01	4.88214E-01	2.03893E-01
9.78000E-01	4.81176E-01	2.08831E-01
9.80000E-01	4.73848E-01	2.14056E-01
9.82000E-01	4.66186E-01	2.19611E-01
9.84000E-01	4.58132E-01	2.25553E-01
9.86000E-01	4.49614E-01	2.31957E-01
9.88000E-01	4.40527E-01	2.38925E-01
9.90000E-01	4.30725E-01	2.46605E-01
9.92000E-01	4.19979E-01	2.55225E-01
9.94000E-01	4.07910E-01	2.65165E-01
9.96000E-01	3.93772E-01	2.77170E-01
9.98000E-01	3.75645E-01	2.93160E-01
9.99000E-01	3.63037E-01	3.04699E-01
1.00000E-00	3.33333E-01	3.33333E-01

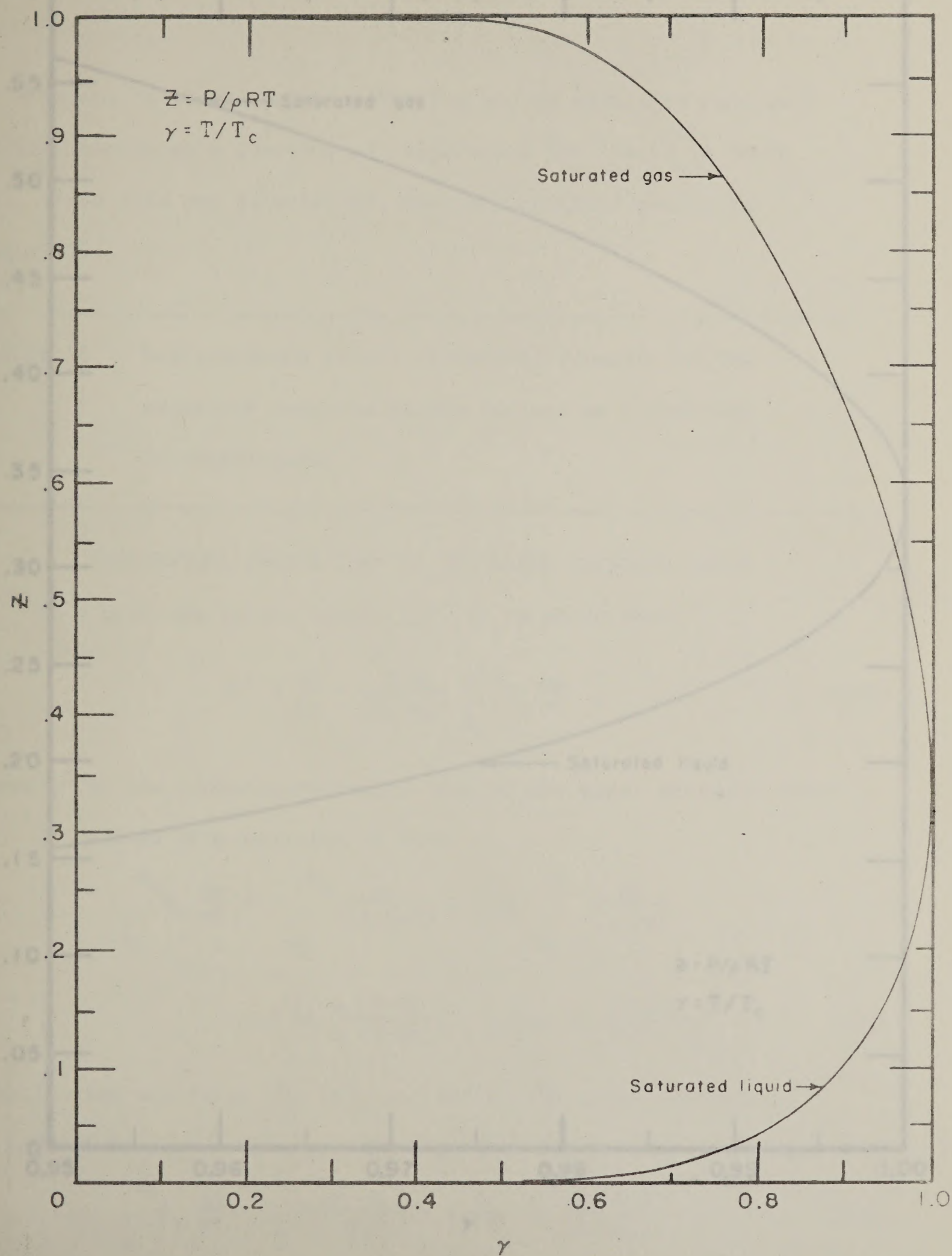


FIGURE 17.- Redlich-Kwong Fluid, Saturated Compressibility Factors as a Function of Temperature.

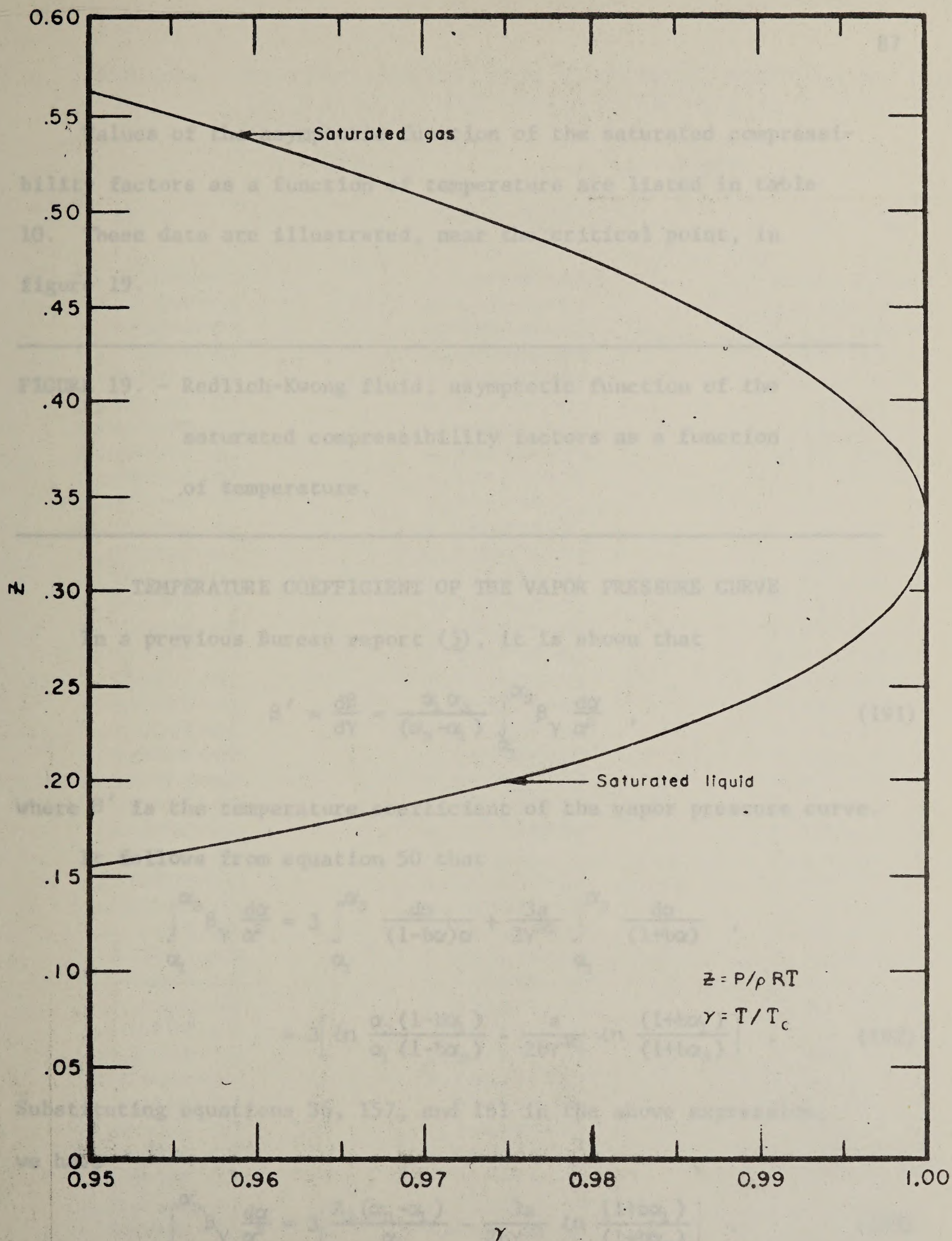


FIGURE 18.— Redlich-Kwong Fluid, Saturated Compressibility Factors as a Function of Temperature Near the Critical Point.

Values of the asymptotic function of the saturated compressibility factors as a function of temperature are listed in table 10. These data are illustrated, near the critical point, in figure 19.

FIGURE 19. - Redlich-Kwong fluid, asymptotic function of the saturated compressibility factors as a function of temperature.

TEMPERATURE COEFFICIENT OF THE VAPOR PRESSURE CURVE

In a previous Bureau report (5), it is shown that

$$\beta' = \frac{d\beta}{dY} = \frac{\alpha_1 \alpha_3}{(\alpha_3 - \alpha_1)} \int_{\alpha_1}^{\alpha_3} \beta_Y \frac{d\alpha}{\alpha^2}, \quad (191)$$

where β' is the temperature coefficient of the vapor pressure curve.

It follows from equation 50 that

$$\begin{aligned} \int_{\alpha_1}^{\alpha_3} \beta_Y \frac{d\alpha}{\alpha^2} &= 3 \int_{\alpha_1}^{\alpha_3} \frac{d\alpha}{(1-b\alpha)\alpha} + \frac{3a}{2Y^{3/2}} \int_{\alpha_1}^{\alpha_3} \frac{d\alpha}{(1+b\alpha)} \\ &= 3 \left[\ln \frac{\alpha_3(1-b\alpha_1)}{\alpha_1(1-b\alpha_3)} - \frac{a}{2bY^{3/2}} \ln \frac{(1+b\alpha_1)}{(1+b\alpha_3)} \right]. \end{aligned} \quad (192)$$

Substituting equations 36, 157, and 161 in the above expression, we have

$$\int_{\alpha_1}^{\alpha_3} \beta_Y \frac{d\alpha}{\alpha^2} = 3 \left[\frac{Z_3(\alpha_3 - \alpha_1)}{\alpha_1} - \frac{3a}{2bY^{3/2}} \ln \frac{(1+b\alpha_1)}{(1+b\alpha_3)} \right]. \quad (193)$$

TABLE 10. - REDLICH-KWONG FLUID, ASYMPTOTIC FUNCTION OF THE SATURATED COMPRESSIBILITY FACTORS AS A FUNCTION OF TEMPERATURE

$\gamma = T/T_c$	$Z = P/\rho RT$	
(1- γ)	$(Z_1 - Z_c)^2$	$(Z_3 - Z_c)^2$
1.00000E+00	4.44444E-01	1.11111E-01
9.00000E-01	4.44444E-01	1.11111E-01
8.50000E-01	4.44444E-01	1.11111E-01
8.00000E-01	4.44444E-01	1.11111E-01
7.50000E-01	4.44444E-01	1.11111E-01
7.00000E-01	4.44443E-01	1.11111E-01
6.50000E-01	4.44421E-01	1.11110E-01
6.00000E-01	4.44146E-01	1.11102E-01
5.50000E-01	4.42625E-01	1.11042E-01
5.00000E-01	4.37679E-01	1.10801E-01
4.50000E-01	4.26423E-01	1.10120E-01
4.00000E-01	4.06387E-01	1.08617E-01
3.50000E-01	3.76328E-01	1.05834E-01
3.00000E-01	3.36396E-01	1.01275E-01
2.50000E-01	2.87857E-01	9.44260E-02
2.00000E-01	2.32699E-01	8.47511E-02
1.50000E-01	1.73317E-01	7.16466E-02
1.00000E-01	1.12372E-01	5.43335E-02
5.00000E-02	5.29262E-02	3.15676E-02
4.80000E-02	5.06333E-02	3.05140E-02
4.60000E-02	4.83499E-02	2.94474E-02
4.40000E-02	4.60763E-02	2.83675E-02
4.20000E-02	4.38129E-02	2.72741E-02
4.00000E-02	4.15603E-02	2.61667E-02
3.80000E-02	3.93188E-02	2.50451E-02
3.60000E-02	3.70891E-02	2.39087E-02
3.40000E-02	3.48715E-02	2.27572E-02
3.20000E-02	3.26667E-02	2.15901E-02
3.00000E-02	3.04753E-02	2.04069E-02
2.80000E-02	2.82979E-02	1.92070E-02
2.60000E-02	2.61353E-02	1.79898E-02
2.40000E-02	2.39883E-02	1.67546E-02
2.20000E-02	2.18577E-02	1.55006E-02
2.00000E-02	1.97445E-02	1.42269E-02
1.80000E-02	1.76498E-02	1.29326E-02
1.60000E-02	1.55749E-02	1.16165E-02
1.40000E-02	1.35212E-02	1.02771E-02
1.20000E-02	1.14906E-02	8.91289E-03
1.00000E-02	9.48516E-03	7.52169E-03
8.00000E-03	7.50761E-03	6.10088E-03
6.00000E-03	5.56169E-03	4.64683E-03
4.00000E-03	3.65284E-03	3.15423E-03
2.00000E-03	1.79035E-03	1.61384E-03
1.00000E-03	8.82350E-04	8.19907E-04
0.00000E-99	0.00000E-99	0.00000E-99

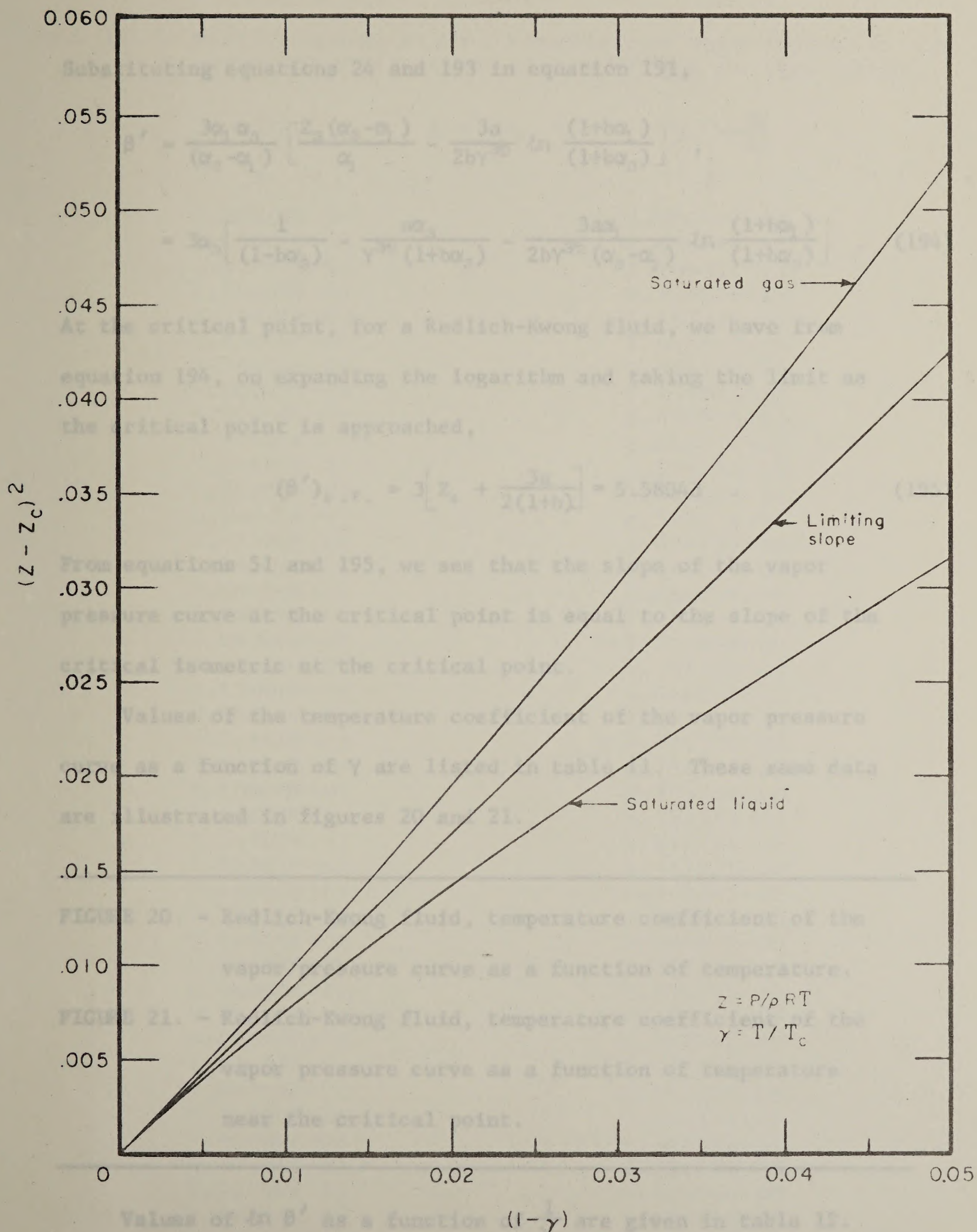


FIGURE 19.—Redlich-Kwong Fluid, Asymptotic Function of the Saturated Compressibility Factors as a Function of Temperature.

Substituting equations 24 and 193 in equation 191,

$$\begin{aligned}\beta' &= \frac{3\alpha_1\alpha_3}{(\alpha_3-\alpha_1)} \left[\frac{Z_3(\alpha_3-\alpha_1)}{\alpha_1} - \frac{3a}{2b\gamma^{3/2}} \ln \frac{(1+b\alpha_1)}{(1+b\alpha_3)} \right], \\ &= 3\alpha_3 \left[\frac{1}{(1-b\alpha_3)} - \frac{a\alpha_3}{\gamma^{3/2}(1+b\alpha_3)} - \frac{3a\alpha_1}{2b\gamma^{3/2}(\alpha_3-\alpha_1)} \ln \frac{(1+b\alpha_1)}{(1+b\alpha_3)} \right]. \quad (194)\end{aligned}$$

At the critical point, for a Redlich-Kwong fluid, we have from equation 194, on expanding the logarithm and taking the limit as the critical point is approached,

$$(\beta')_{c.p.} = 3 \left[Z_c + \frac{3a}{2(1+b)} \right] = 5.58043. \quad (195)$$

From equations 51 and 195, we see that the slope of the vapor pressure curve at the critical point is equal to the slope of the critical isometric at the critical point.

Values of the temperature coefficient of the vapor pressure curve as a function of γ are listed in table 11. These same data are illustrated in figures 20 and 21.

FIGURE 20. - Redlich-Kwong fluid, temperature coefficient of the vapor pressure curve as a function of temperature.

FIGURE 21. - Redlich-Kwong fluid, temperature coefficient of the vapor pressure curve as a function of temperature near the critical point.

Values of $\ln \beta'$ as a function of $\frac{1}{\gamma}$ are given in table 12.

Substituting equations 19 and 20 in equation 18,

$$h' = \frac{3\alpha_1 \alpha_2}{(\alpha_1 - \alpha_2)} - \frac{2(\alpha_1 - \alpha_2)}{\alpha_1} - \frac{2\alpha_2}{2\alpha_1 \alpha_2} \ln \frac{(1+\alpha_1)}{(1+\alpha_2)}$$

$$= 3\alpha_1 \left[\frac{1}{(1-\alpha_1)} - \frac{\alpha_2}{\alpha_1(1+\alpha_1)} - \frac{\alpha_2}{2\alpha_1 \alpha_2 (\alpha_1 - \alpha_2)} \ln \frac{(1+\alpha_1)}{(1+\alpha_2)} \right] \quad (19)$$

At the critical point, for a Redlich-Kwong fluid, we have from equation 18, on expanding the logarithm and taking the limit as the critical point is approached,

$$(h')_{c.p.} = 3 \left[\frac{1}{2} + \frac{3\alpha_2}{2(1+\alpha_2)} \right] = 2.38623 \quad (20)$$

From equations 19 and 20, we see that the slope of the vapor pressure curve at the critical point is equal to the slope of the critical isobaric at the critical point.

Values of the temperature coefficient of the vapor pressure curve as a function of γ are listed in table 11. These same data are illustrated in figures 10 and 11.

FIGURE 10. - Redlich-Kwong fluid, temperature coefficient of the

vapor pressure curve as a function of temperature.

FIGURE 11. - Redlich-Kwong fluid, temperature coefficient of the

vapor pressure curve as a function of temperature.

near the critical point.

Values of h' as a function of γ are given in table 12.

TABLE 11. - REDLICH-KWONG FLUID, TEMPERATURE COEFFICIENT OF THE VAPOR PRESSURE CURVE AS A FUNCTION OF TEMPERATURE

$\gamma = T/T_c$	$\beta = P/P_c$	$\beta' = \frac{d\beta}{d\gamma}$
γ		β'
0.00000E-99		0.00000E-99
1.00000E-01		1.55088E-42
1.50000E-01		1.14690E-21
2.00000E-01		4.35885E-13
2.50000E-01		1.16262E-08
3.00000E-01		4.60366E-06
3.50000E-01		2.08613E-04
4.00000E-01		2.73798E-03
4.50000E-01		1.67639E-02
5.00000E-01		6.26287E-02
5.50000E-01		1.67943E-01
6.00000E-01		3.58404E-01
6.50000E-01		6.51267E-01
7.00000E-01		1.05418E-00
7.50000E-01		1.56731E-00
8.00000E-01		2.18623E-00
8.50000E-01		2.90422E-00
9.00000E-01		3.71389E-00
9.50000E-01		4.60810E-00
9.52000E-01		4.64553E-00
9.54000E-01		4.68309E-00
9.56000E-01		4.72077E-00
9.58000E-01		4.75857E-00
9.60000E-01		4.79650E-00
9.62000E-01		4.83455E-00
9.64000E-01		4.87273E-00
9.66000E-01		4.91102E-00
9.68000E-01		4.94944E-00
9.70000E-01		4.98798E-00
9.72000E-01		5.02664E-00
9.74000E-01		5.06543E-00
9.76000E-01		5.10433E-00
9.78000E-01		5.14335E-00
9.80000E-01		5.18249E-00
9.82000E-01		5.22175E-00
9.84000E-01		5.26114E-00
9.86000E-01		5.30063E-00
9.88000E-01		5.34025E-00
9.90000E-01		5.37999E-00
9.92000E-01		5.41984E-00
9.94000E-01		5.45981E-00
9.96000E-01		5.49990E-00
9.98000E-01		5.54011E-00
9.99000E-01		5.56025E-00
1.00000E-00		5.58043E-00

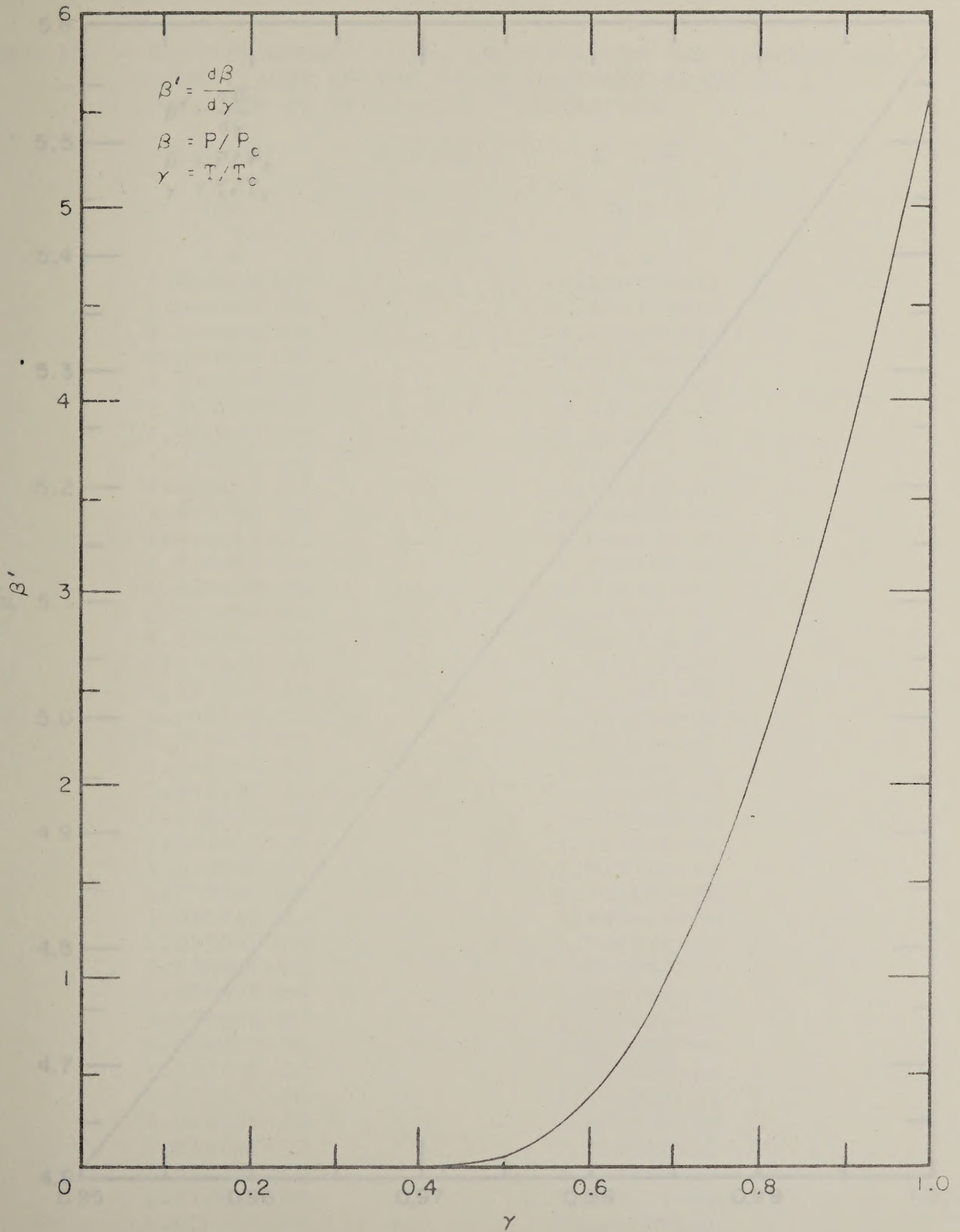


FIGURE 20. - Redlich-Kwong Fluid, Temperature Coefficient of the Vapor Pressure Curve as a Function of Temperature.

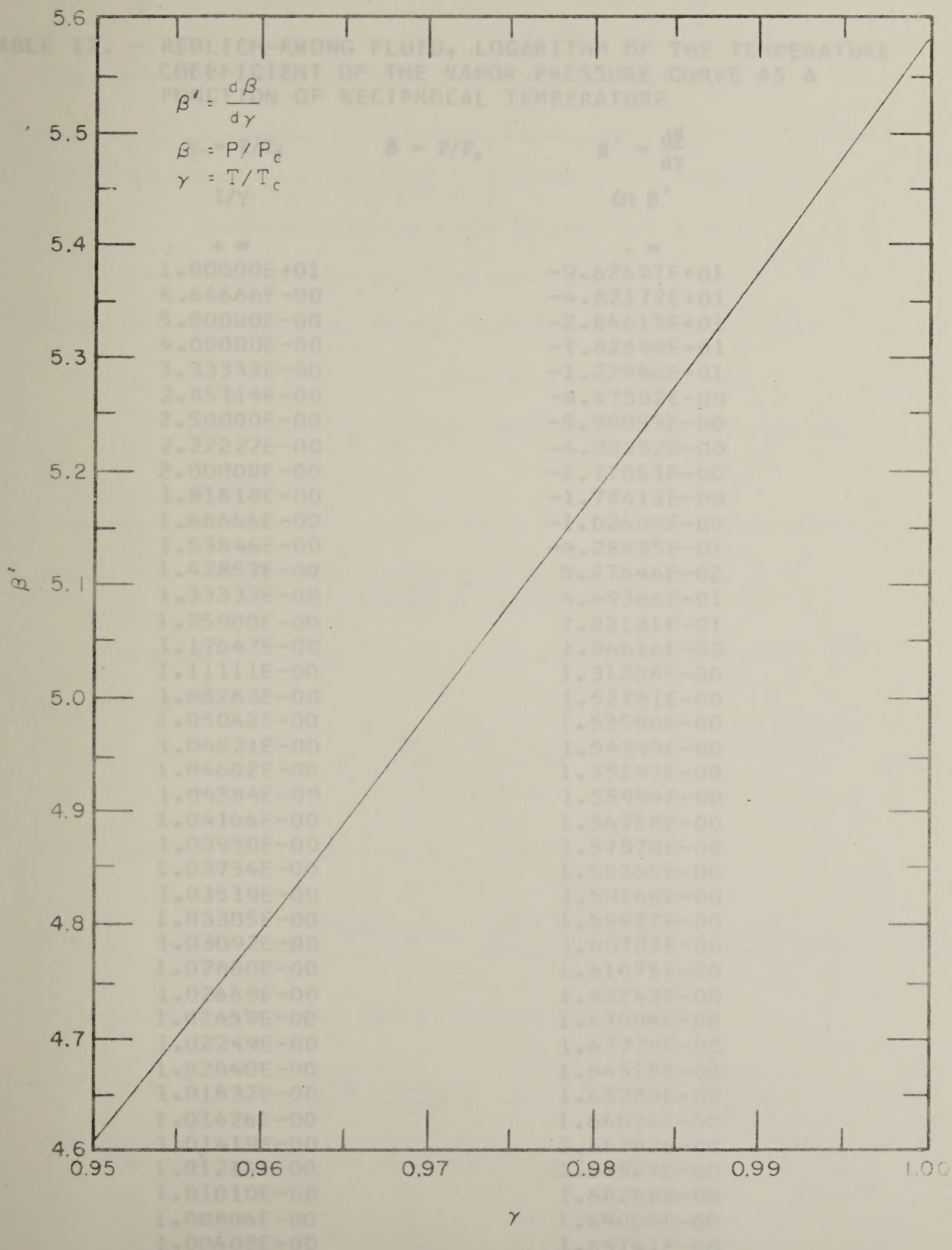


FIGURE 21. - Redlich-Kwong Fluid, Temperature Coefficient of the Vapor Pressure Curve as a Function of Temperature Near the Critical Point.

TABLE 12. - REDLICH-KWONG FLUID, LOGARITHM OF THE TEMPERATURE COEFFICIENT OF THE VAPOR PRESSURE CURVE AS A FUNCTION OF RECIPROCAL TEMPERATURE

$\gamma = T/T_c$	$\beta = P/P_c$	$\beta' = \frac{d\beta}{d\gamma}$
$1/\gamma$		$\ln \beta'$
$+\infty$		$-\infty$
1.00000E+01		-9.62697E+01
6.66666E-00		-4.82172E+01
5.00000E-00		-2.84613E+01
4.00000E-00		-1.82699E+01
3.33333E-00		-1.22886E+01
2.85714E-00		-8.47502E-00
2.50000E-00		-5.90053E-00
2.22222E-00		-4.08852E-00
2.00000E-00		-2.77053E-00
1.81818E-00		-1.78413E-00
1.66666E-00		-1.02609E-00
1.53846E-00		-4.28835E-01
1.42857E-00		5.27646E-02
1.33333E-00		4.49366E-01
1.25000E-00		7.82181E-01
1.17647E-00		1.06616E-00
1.11111E-00		1.31208E-00
1.05263E-00		1.52781E-00
1.05042E-00		1.53590E-00
1.04821E-00		1.54395E-00
1.04602E-00		1.55197E-00
1.04384E-00		1.55994E-00
1.04166E-00		1.56788E-00
1.03950E-00		1.57578E-00
1.03734E-00		1.58365E-00
1.03519E-00		1.59148E-00
1.03305E-00		1.59927E-00
1.03092E-00		1.60703E-00
1.02880E-00		1.61475E-00
1.02669E-00		1.62243E-00
1.02459E-00		1.63008E-00
1.02249E-00		1.63770E-00
1.02040E-00		1.64528E-00
1.01832E-00		1.65283E-00
1.01626E-00		1.66034E-00
1.01419E-00		1.66782E-00
1.01214E-00		1.67527E-00
1.01010E-00		1.68268E-00
1.00806E-00		1.69006E-00
1.00603E-00		1.69741E-00
1.00401E-00		1.70473E-00
1.00200E-00		1.71201E-00
1.00100E-00		1.71564E-00
1.00000E-00		1.71926E-00

These same data are illustrated in figures 22 and 23.

FIGURE 22. - Redlich-Kwong fluid, logarithm of the temperature coefficient of the vapor pressure curve as a function of reciprocal temperature.

FIGURE 23. - Redlich-Kwong fluid, logarithm of the temperature coefficient of the vapor pressure curve as a function of reciprocal temperature near the critical point.

TEMPERATURE COEFFICIENTS OF THE SATURATED LIQUID AND GAS DENSITIES

The temperature coefficient of the saturated gas density, $\frac{d\alpha_1}{d\gamma}$, is given as (5),

$$\alpha_1' = \frac{d\alpha_1}{d\gamma} = \frac{\beta' - \beta_{\gamma(1)}}{\beta_{\alpha(1)}} \quad (196)$$

From equations 23, 29, 50, and 194, we find that

$$\beta' - \beta_{\gamma(1)} = 3\alpha_3 Z_3 - \frac{9a\alpha_1 \alpha_3}{2b(\alpha_3 - \alpha_1)\gamma^{3/2}} \ln \frac{(1+b\alpha_1)}{(1+b\alpha_3)} - 3\alpha_1 Z_1 - \frac{9a\alpha_1^2}{2(1+b\alpha_1)\gamma^{3/2}} \quad (197)$$

or, substituting equation 157 in equation 197, we have

$$\beta' - \beta_{\gamma(1)} = - \frac{9a\alpha_1}{2\gamma^{3/2}} \left[\frac{\alpha_1}{(1+b\alpha_1)} - \frac{\alpha_3}{b(\alpha_3 - \alpha_1)} \ln \frac{(1+b\alpha_3)}{(1+b\alpha_1)} \right] \quad (198)$$

From equation 52, for the saturated gas, we have

$$\beta_{\alpha(1)} = 3\gamma \left[\frac{1}{(1-b\alpha_1)^2} - \frac{a\alpha_1 (2+b\alpha_1)}{\gamma^{3/2} (1+b\alpha_1)^2} \right] \quad (199)$$

These same data are illustrated in Figures 22 and 23.

FIGURE 22. - Redlich-Kwong fluid, logarithm of the temperature coefficient of the vapor pressure curve as a function of reduced temperature.

FIGURE 23. - Redlich-Kwong fluid, logarithm of the temperature coefficient of the vapor pressure curve as a function of reduced temperature near the critical point.

TEMPERATURE COEFFICIENTS OF THE SATURATED LIQUID AND GAS DENSITIES

The temperature coefficient of the saturated gas density, $\frac{d\rho_g}{dT}$, is given as (19):

$$\frac{d\rho_g}{dT} = \frac{\rho_g}{T} \left[\frac{1}{1 - \alpha} - \frac{1}{1 - \alpha^2} \right] \quad (19)$$

From equations 21, 22, 23, and 24, we find that

$$\frac{d\rho_g}{dT} = \frac{\rho_g}{T} \left[\frac{1}{1 - \alpha} - \frac{1}{1 - \alpha^2} \right] \ln \left(\frac{1 + \alpha}{1 - \alpha} \right) - \frac{\rho_g}{T} \frac{1}{1 - \alpha^2} \quad (20)$$

or, substituting equation 15 in equation 19, we have

$$\frac{d\rho_g}{dT} = \frac{\rho_g}{T} \left[\frac{1}{1 - \alpha} - \frac{1}{1 - \alpha^2} \right] \ln \left(\frac{1 + \alpha}{1 - \alpha} \right) - \frac{\rho_g}{T} \frac{1}{1 - \alpha^2} \quad (21)$$

From equation 22, for the saturated gas, we have

$$\frac{d\rho_g}{dT} = \frac{\rho_g}{T} \left[\frac{1}{1 - \alpha} - \frac{1}{1 - \alpha^2} \right] \ln \left(\frac{1 + \alpha}{1 - \alpha} \right) - \frac{\rho_g}{T} \frac{1}{1 - \alpha^2} \quad (22)$$

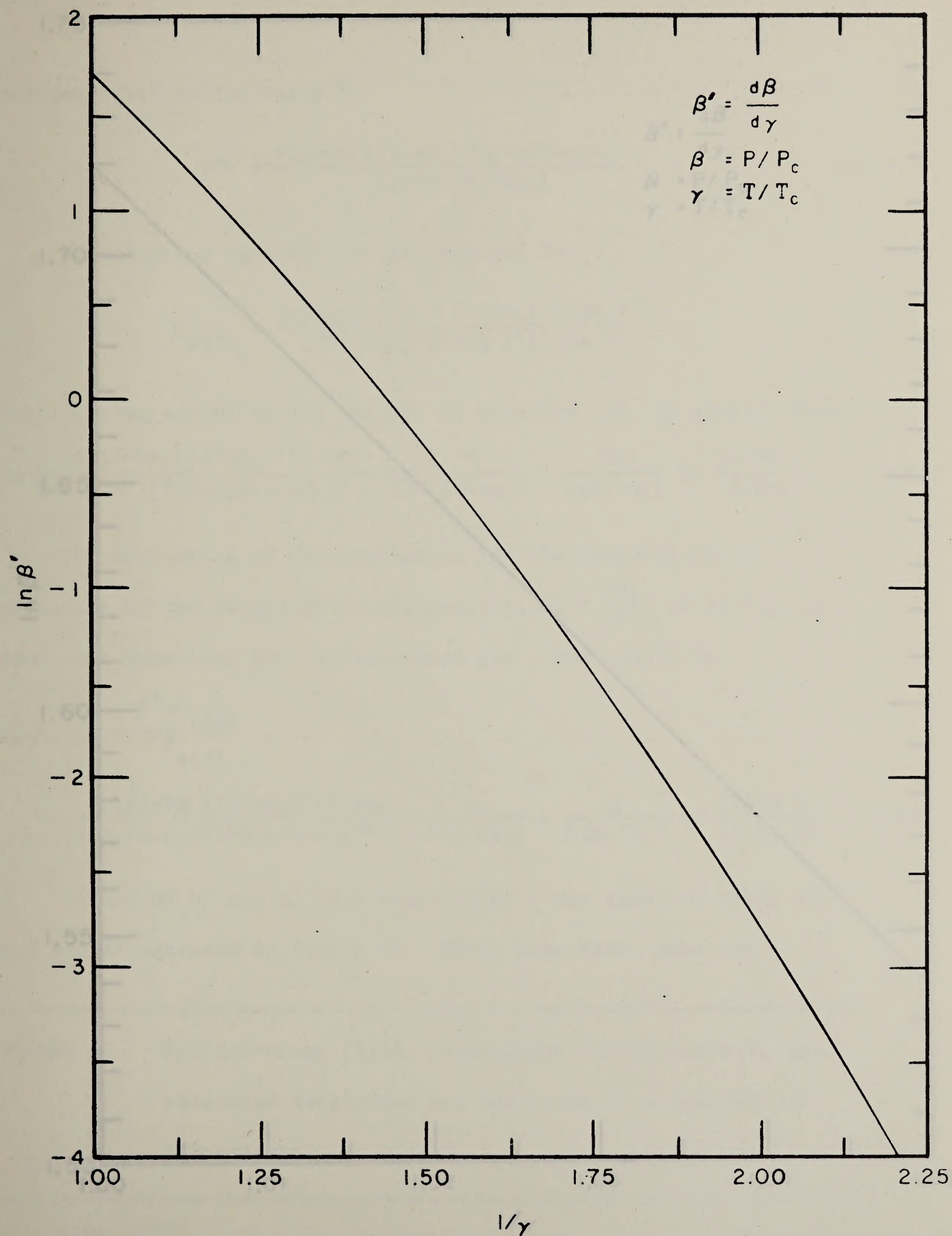


FIGURE 22. - Redlich-Kwong Fluid, Logarithm of the Temperature Coefficient of the Vapor Pressure Curve as a Function of Reciprocal Temperature.

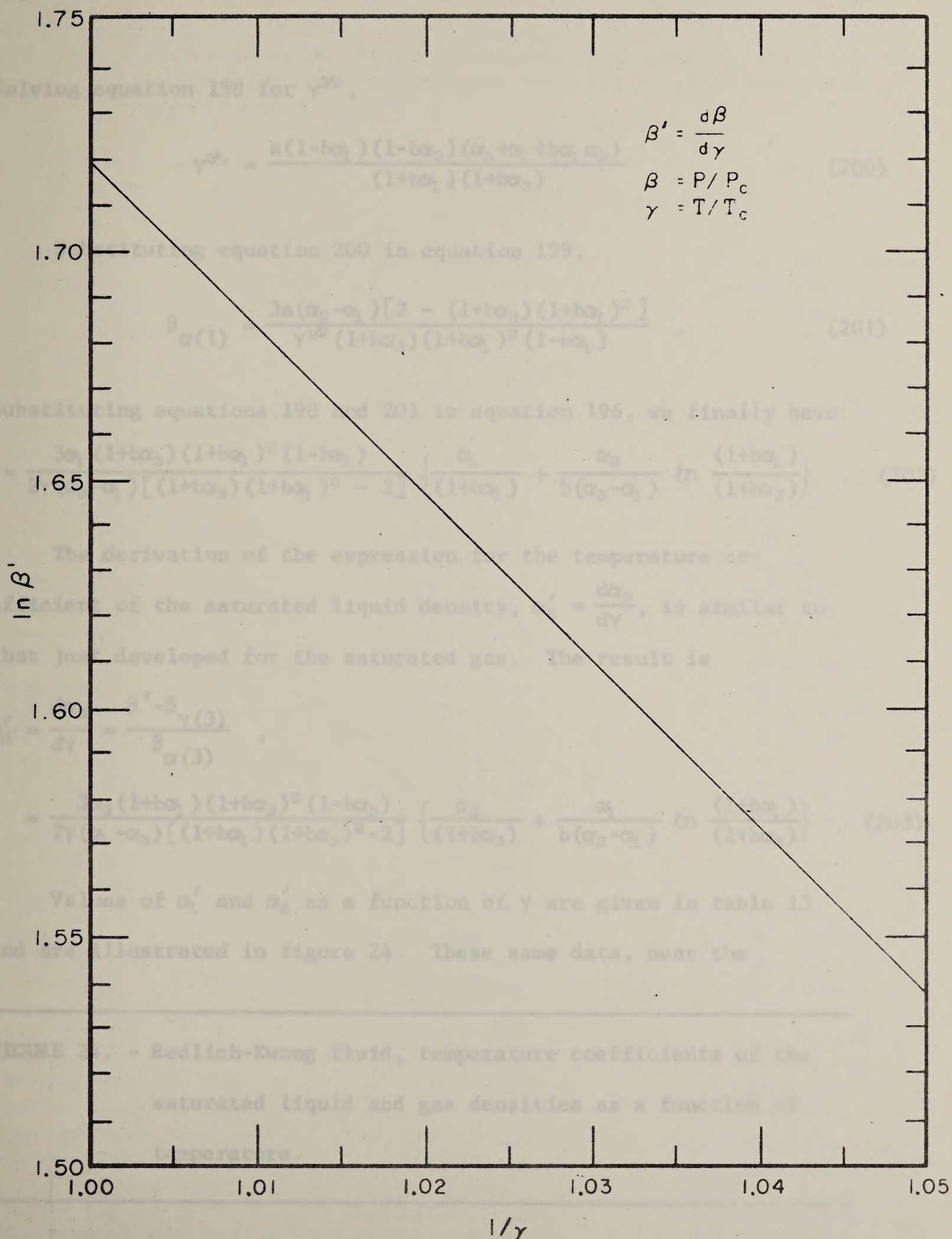


FIGURE 23. - Redlich-Kwong Fluid, Logarithm of the Temperature Coefficient of the Vapor Pressure Curve as a Function of Reciprocal Temperature Near the Critical Point.

Solving equation 158 for $\gamma^{3/2}$,

$$\gamma^{3/2} = \frac{a(1-b\alpha_1)(1-b\alpha_3)(\alpha_3+\alpha_1+b\alpha_1\alpha_3)}{(1+b\alpha_1)(1+b\alpha_3)} \quad (200)$$

Substituting equation 200 in equation 199,

$$\beta_{\alpha(1)} = \frac{3a(\alpha_3-\alpha_1)[2 - (1+b\alpha_3)(1+b\alpha_1)^2]}{\gamma^{1/2}(1+b\alpha_3)(1+b\alpha_1)^2(1-b\alpha_1)} \quad (201)$$

Substituting equations 198 and 201 in equation 196, we finally have

$$\alpha_1' = \frac{3\alpha_1(1+b\alpha_3)(1+b\alpha_1)^2(1-b\alpha_1)}{2\gamma(\alpha_3-\alpha_1)[(1+b\alpha_3)(1+b\alpha_1)^2 - 2]} \left\{ \frac{\alpha_1}{(1+b\alpha_1)} + \frac{\alpha_3}{b(\alpha_3-\alpha_1)} \ln \frac{(1+b\alpha_1)}{(1+b\alpha_3)} \right\} \quad (202)$$

The derivation of the expression for the temperature coefficient of the saturated liquid density, $\alpha_3' = \frac{d\alpha_3}{d\gamma}$, is similar to that just developed for the saturated gas. The result is

$$\begin{aligned} \alpha_3' &= \frac{d\alpha_3}{d\gamma} = \frac{\beta' - \beta_{\gamma(3)}}{\beta_{\alpha(3)}}, \\ &= \frac{3\alpha_3(1+b\alpha_1)(1+b\alpha_3)^2(1-b\alpha_3)}{2\gamma(\alpha_1-\alpha_3)[(1+b\alpha_1)(1+b\alpha_3)^2 - 2]} \left\{ \frac{\alpha_3}{(1+b\alpha_3)} + \frac{\alpha_1}{b(\alpha_3-\alpha_1)} \ln \frac{(1+b\alpha_1)}{(1+b\alpha_3)} \right\} \quad (203) \end{aligned}$$

Values of α_1' and α_3' as a function of γ are given in table 13 and are illustrated in figure 24. These same data, near the

FIGURE 24. - Redlich-Kwong fluid, temperature coefficients of the saturated liquid and gas densities as a function of temperature.

TABLE 13. - REDLICH-KWONG FLUID, TEMPERATURE COEFFICIENTS OF THE SATURATED LIQUID AND GAS DENSITIES AS A FUNCTION OF TEMPERATURE

$\gamma = T/T_c$	$\alpha = \rho/\rho_c$	$\alpha' = \frac{d\alpha}{d\gamma}$
γ	α_1	α_3
0.00000E-99	0.00000E-99	0.00000E-99
1.00000E-01	5.13765E-42	-7.49513E-01
1.50000E-01	2.51964E-21	-9.28538E-01
2.00000E-01	7.13688E-13	-1.08748E-00
2.50000E-01	1.51187E-08	-1.23662E-00
3.00000E-01	4.94822E-06	-1.38192E-00
3.50000E-01	1.90465E-04	-1.52777E-00
4.00000E-01	2.16643E-03	-1.67811E-00
4.50000E-01	1.16883E-02	-1.83694E-00
5.00000E-01	3.91147E-02	-2.00860E-00
5.50000E-01	9.56997E-02	-2.19798E-00
6.00000E-01	1.90295E-01	-2.41099E-00
6.50000E-01	3.29859E-01	-2.65546E-00
7.00000E-01	5.22812E-01	-2.94293E-00
7.50000E-01	7.84099E-01	-3.29211E-00
8.00000E-01	1.14387E-00	-3.73661E-00
8.50000E-01	1.66868E-00	-4.34586E-00
9.00000E-01	2.53427E-00	-5.29781E-00
9.50000E-01	4.43884E-00	-7.29240E-00
9.52000E-01	4.57124E-00	-7.42850E-00
9.54000E-01	4.71201E-00	-7.57297E-00
9.56000E-01	4.86208E-00	-7.72675E-00
9.58000E-01	5.02254E-00	-7.89092E-00
9.60000E-01	5.19466E-00	-8.06677E-00
9.62000E-01	5.37995E-00	-8.25580E-00
9.64000E-01	5.58021E-00	-8.45980E-00
9.66000E-01	5.79759E-00	-8.68094E-00
9.68000E-01	6.03472E-00	-8.92183E-00
9.70000E-01	6.29482E-00	-9.18571E-00
9.72000E-01	6.58192E-00	-9.47658E-00
9.74000E-01	6.90108E-00	-9.79952E-00
9.76000E-01	7.25882E-00	-1.01610E+01
9.78000E-01	7.66371E-00	-1.05697E+01
9.80000E-01	8.12722E-00	-1.10370E+01
9.82000E-01	8.66515E-00	-1.15788E+01
9.84000E-01	9.30006E-00	-1.22175E+01
9.86000E-01	1.00653E+01	-1.29867E+01
9.88000E-01	1.10132E+01	-1.39384E+01
9.90000E-01	1.22308E+01	-1.51599E+01
9.92000E-01	1.38776E+01	-1.68105E+01
9.94000E-01	1.62865E+01	-1.92234E+01
9.96000E-01	2.03204E+01	-2.32611E+01
9.98000E-01	2.94087E+01	-3.23533E+01
9.99000E-01	4.22445E+01	-4.51910E+01
1.00000E-00	+ ∞	- ∞

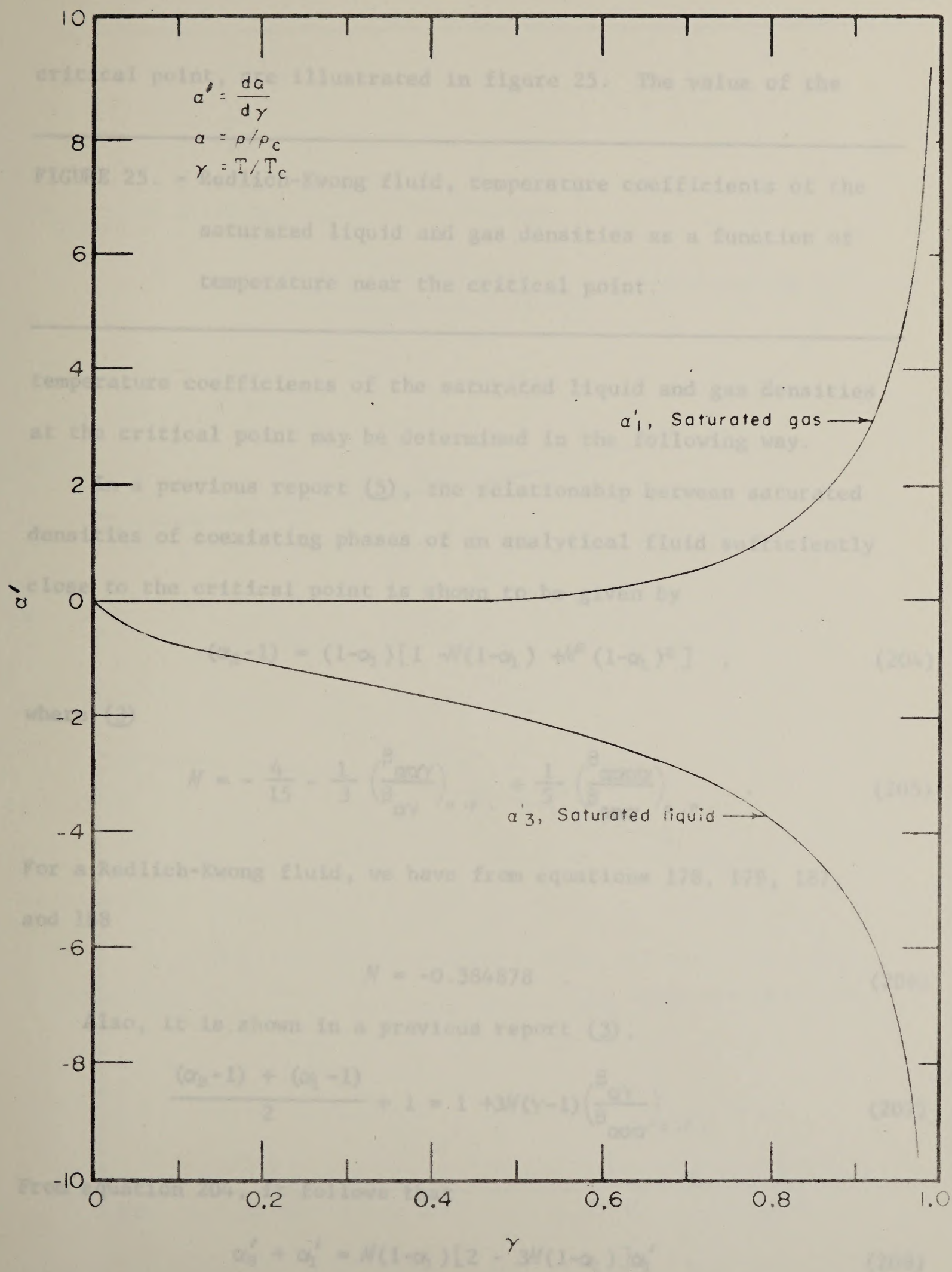


FIGURE 24.- Redlich-Kwong Fluid, Temperature Coefficients of the Saturated Liquid and Gas Densities as a Function of Temperature.

critical point, are illustrated in figure 25. The value of the

FIGURE 25. - Redlich-Kwong fluid, temperature coefficients of the saturated liquid and gas densities as a function of temperature near the critical point.

temperature coefficients of the saturated liquid and gas densities at the critical point may be determined in the following way.

In a previous report (5), the relationship between saturated densities of coexisting phases of an analytical fluid sufficiently close to the critical point is shown to be given by

$$(\alpha_3 - 1) = (1 - \alpha_1) [1 - M(1 - \alpha_1) + M^2 (1 - \alpha_1)^2] , \quad (204)$$

where (3)

$$M = -\frac{4}{15} - \frac{1}{3} \left(\frac{\beta_{\alpha\alpha\gamma}}{\beta_{\alpha\gamma}} \right)_{c.p.} + \frac{1}{5} \left(\frac{\beta_{\alpha\alpha\alpha\alpha}}{\beta_{\alpha\alpha\alpha}} \right)_{c.p.} . \quad (205)$$

For a Redlich-Kwong fluid, we have from equations 178, 179, 187, and 188

$$M = -0.384878 . \quad (206)$$

Also, it is shown in a previous report (3),

$$\frac{(\alpha_3 - 1) + (\alpha_1 - 1)}{2} + 1 = 1 + 3M(\gamma - 1) \left(\frac{\beta_{\alpha\gamma}}{\beta_{\alpha\alpha\alpha}} \right)_{c.p.} . \quad (207)$$

From equation 204, it follows that

$$\alpha'_3 + \alpha'_1 = M(1 - \alpha_1) [2 - 3M(1 - \alpha_1)] \alpha'_1 . \quad (208)$$

FIGURE 25. - Redlich-Kwong Fluid, Temperature Coefficients of the Saturated Liquid and Gas Densities as a Function of Temperature Near the Critical Point.

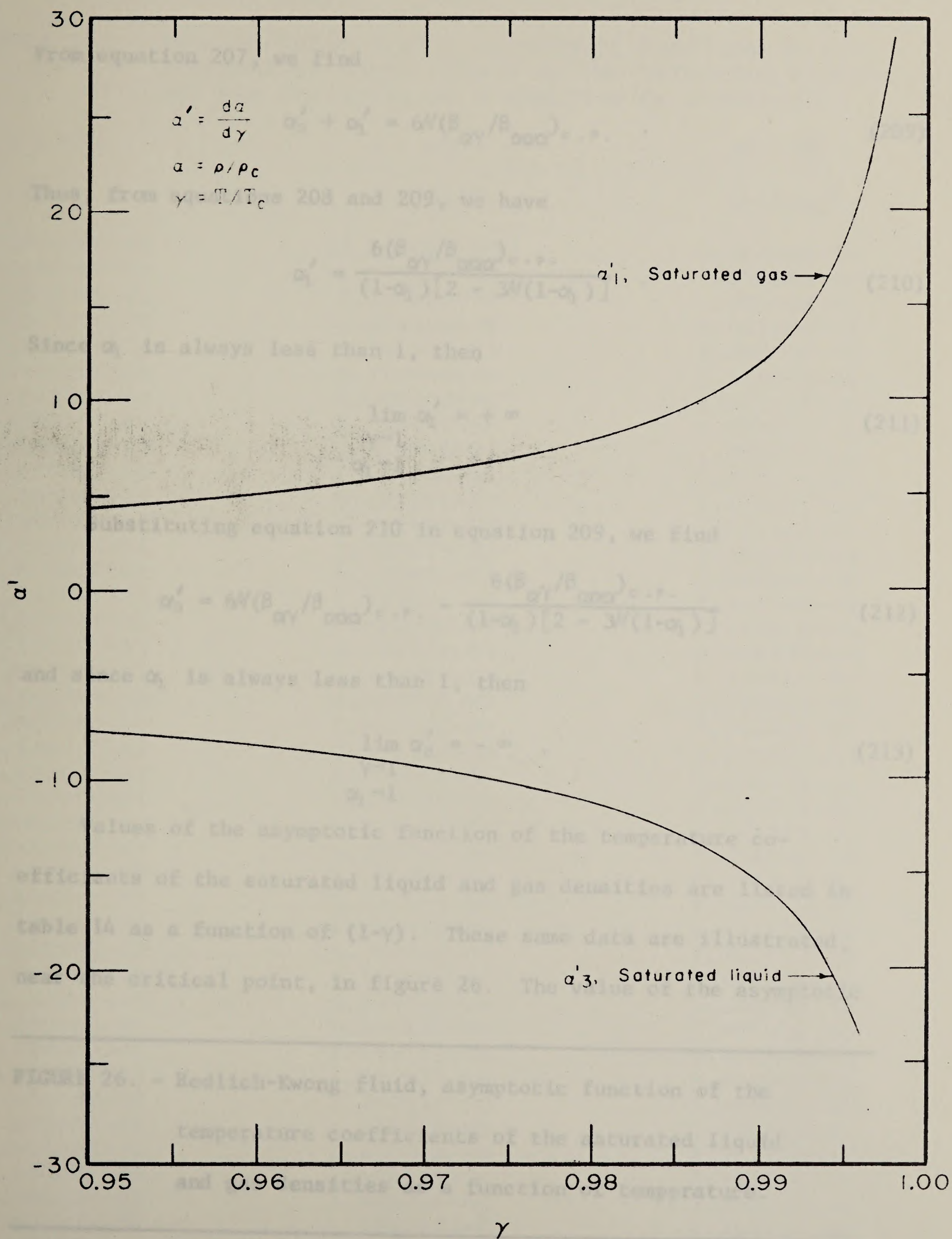


FIGURE 25. - Redlich-Kwong Fluid, Temperature Coefficients of the Saturated Liquid and Gas Densities as a Function of Temperature Near the Critical Point.

From equation 207, we find

$$\alpha'_3 + \alpha'_1 = 6M(\beta_{\alpha\gamma}/\beta_{\alpha\alpha\alpha})_{c.p.} \quad (209)$$

Thus, from equations 208 and 209, we have

$$\alpha'_1 = \frac{6(\beta_{\alpha\gamma}/\beta_{\alpha\alpha\alpha})_{c.p.}}{(1-\alpha_1)[2 - 3M(1-\alpha_1)]} \quad (210)$$

Since α_1 is always less than 1, then

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha_1 \rightarrow 1}} \alpha'_1 = +\infty \quad (211)$$

Substituting equation 210 in equation 209, we find

$$\alpha'_3 = 6M(\beta_{\alpha\gamma}/\beta_{\alpha\alpha\alpha})_{c.p.} - \frac{6(\beta_{\alpha\gamma}/\beta_{\alpha\alpha\alpha})_{c.p.}}{(1-\alpha_1)[2 - 3M(1-\alpha_1)]} \quad (212)$$

and since α_1 is always less than 1, then

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha_1 \rightarrow 1}} \alpha'_3 = -\infty \quad (213)$$

Values of the asymptotic function of the temperature coefficients of the saturated liquid and gas densities are listed in table 14 as a function of $(1-\gamma)$. These same data are illustrated, near the critical point, in figure 26. The value of the asymptotic

FIGURE 26. - Redlich-Kwong fluid, asymptotic function of the temperature coefficients of the saturated liquid and gas densities as a function of temperature.

function of the temperature coefficients of the saturated liquid

TABLE 14. - REDLICH-KWONG FLUID, ASYMPTOTIC FUNCTION OF THE TEMPERATURE COEFFICIENTS OF THE SATURATED LIQUID AND GAS DENSITIES AS A FUNCTION OF TEMPERATURE

$\gamma = T/T_c$	$\alpha = \rho/\rho_c$	$\alpha' = \frac{d\alpha}{d\gamma}$
$(1-\gamma)$	$(1-\gamma)(\alpha_1')^2$	$(1-\gamma)(\alpha_3')^2$
1.000000E-00	0.000000E-99	0.000000E-99
9.000000E-01	2.37559E-83	5.05592E-01
8.500000E-01	5.39632E-42	7.32855E-01
8.000000E-01	4.07480E-25	9.46104E-01
7.500000E-01	1.71431E-16	1.14693E-00
7.000000E-01	1.71394E-11	1.33680E-00
6.500000E-01	2.35800E-08	1.51716E-00
6.000000E-01	2.81607E-06	1.68964E-00
5.500000E-01	7.51390E-05	1.85589E-00
5.000000E-01	7.64983E-04	2.01724E-00
4.500000E-01	4.12130E-03	2.17402E-00
4.000000E-01	1.44848E-02	2.32516E-00
3.500000E-01	3.80825E-02	2.46802E-00
3.000000E-01	8.19999E-02	2.59826E-00
2.500000E-01	1.53703E-01	2.70950E-00
2.000000E-01	2.61689E-01	2.79245E-00
1.500000E-01	4.17678E-01	2.83297E-00
1.000000E-01	6.42252E-01	2.80668E-00
5.000000E-02	9.85167E-01	2.65895E-00
4.800000E-02	1.00302E-00	2.64876E-00
4.600000E-02	1.02134E-00	2.63809E-00
4.400000E-02	1.04015E-00	2.62691E-00
4.200000E-02	1.05948E-00	2.61520E-00
4.000000E-02	1.07938E-00	2.60291E-00
3.800000E-02	1.09986E-00	2.59001E-00
3.600000E-02	1.12099E-00	2.57646E-00
3.400000E-02	1.14281E-00	2.56219E-00
3.200000E-02	1.16537E-00	2.54717E-00
3.000000E-02	1.18874E-00	2.53131E-00
2.800000E-02	1.21300E-00	2.51455E-00
2.600000E-02	1.23824E-00	2.49679E-00
2.400000E-02	1.26457E-00	2.47793E-00
2.200000E-02	1.29211E-00	2.45783E-00
2.000000E-02	1.32103E-00	2.43634E-00
1.800000E-02	1.35152E-00	2.41325E-00
1.600000E-02	1.38385E-00	2.38830E-00
1.400000E-02	1.41836E-00	2.36116E-00
1.200000E-02	1.45550E-00	2.33136E-00
1.000000E-02	1.49594E-00	2.29824E-00
8.000000E-03	1.54071E-00	2.26076E-00
6.000000E-03	1.59151E-00	2.21723E-00
4.000000E-03	1.65168E-00	2.16432E-00
2.000000E-03	1.72975E-00	2.09348E-00
1.000000E-03	1.78460E-00	2.04223E-00
0.000000E-99	1.91521E-00	1.91521E-00

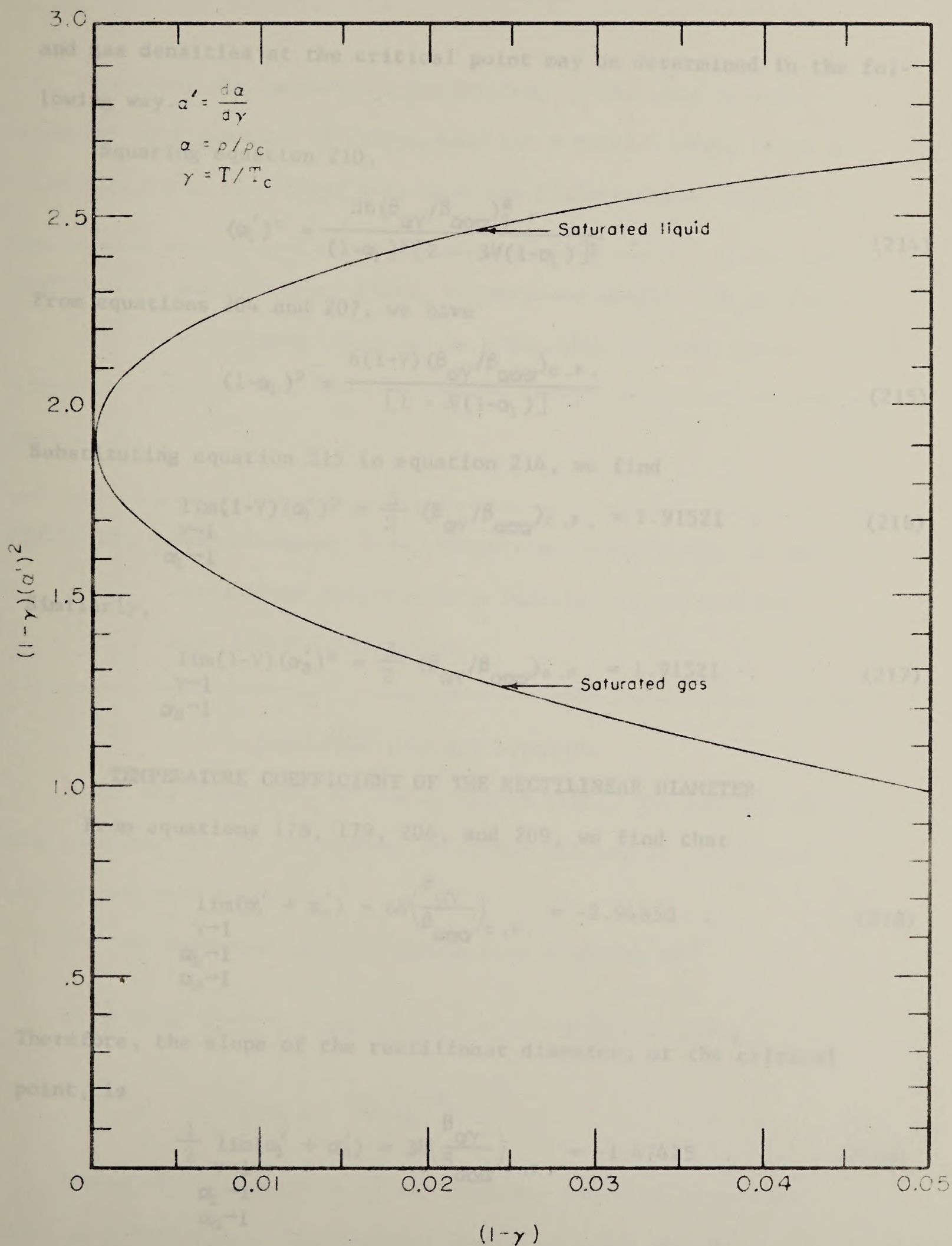


FIGURE 26.- Redlich-Kwong Fluid, Asymptotic Function of the Temperature Coefficients of the Saturated Liquid and Gas Densities as a Function of Temperature.

and gas densities at the critical point may be determined in the following way.

Squaring equation 210,

$$(\alpha'_1)^2 = \frac{36(\beta_{\alpha\gamma}/\beta_{\alpha\alpha\alpha})_{c.p.}^2}{(1-\alpha_1)^2[2 - 3M(1-\alpha_1)]^2} \quad (214)$$

From equations 204 and 207, we have

$$(1-\alpha_1)^2 = \frac{6(1-\gamma)(\beta_{\alpha\gamma}/\beta_{\alpha\alpha\alpha})_{c.p.}}{[1 - M(1-\alpha_1)]} \quad (215)$$

Substituting equation 215 in equation 214, we find

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha_1 \rightarrow 1}} (1-\gamma)(\alpha'_1)^2 = \frac{3}{2} (\beta_{\alpha\gamma}/\beta_{\alpha\alpha\alpha})_{c.p.} = 1.91521 \quad (216)$$

Similarly,

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha_3 \rightarrow 1}} (1-\gamma)(\alpha'_3)^2 = \frac{3}{2} (\beta_{\alpha\gamma}/\beta_{\alpha\alpha\alpha})_{c.p.} = 1.91521 \quad (217)$$

TEMPERATURE COEFFICIENT OF THE RECTILINEAR DIAMETER

From equations 178, 179, 206, and 209, we find that

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha_1 \rightarrow 1 \\ \alpha_3 \rightarrow 1}} (\alpha'_1 + \alpha'_3) = 6M \left(\frac{\beta_{\alpha\gamma}}{\beta_{\alpha\alpha\alpha}} \right)_{c.p.} = -2.94850 \quad (218)$$

Therefore, the slope of the rectilinear diameter, at the critical point, is

$$\frac{1}{2} \lim_{\substack{\gamma \rightarrow 1 \\ \alpha_1 \rightarrow 1 \\ \alpha_3 \rightarrow 1}} (\alpha'_1 + \alpha'_3) = 3M \left(\frac{\beta_{\alpha\gamma}}{\beta_{\alpha\alpha\alpha}} \right)_{c.p.} = -1.47425 \quad (219)$$

Values of the temperature coefficient of the rectilinear diameter as a function of temperature for a Redlich-Kwong fluid are listed in table 15. These same data are illustrated in figures 27

FIGURE 27. - Redlich-Kwong fluid, temperature coefficient of the rectilinear diameter as a function of temperature.

and 28.

FIGURE 28. - Redlich-Kwong fluid, temperature coefficient of the rectilinear diameter as a function of temperature near the critical point.

SATURATED FUGACITY FUNCTION

Since the fugacities of the saturated liquid and gas are the same, one may use the properties of either the gas or the liquid to evaluate this function.

For the saturated gas, we obtain from equation 69

$$\ln \frac{f}{P} = \alpha_1 \left[\frac{b}{(1-b\alpha_1)} - \frac{a}{\gamma^{3/2}(1+b\alpha_1)} \right] + \left[1 - \frac{a}{b\gamma^{3/2}} \right] \ln (1+b\alpha_1) - \ln \left[(1+b\alpha_1) - \frac{a\alpha_1(1-b\alpha_1)}{\gamma^{3/2}} \right] \quad (220)$$

Values of the logarithm of the fugacity function, at saturation, as a function of temperature, listed in table 16, are

TABLE 15. - REDLICH-KWONG FLUID, TEMPERATURE COEFFICIENT OF THE RECTILINEAR DIAMETER AS A FUNCTION OF TEMPERATURE

$\gamma = T/T_c$	$\alpha = \rho/\rho_c$	$\alpha' = \frac{d\alpha}{d\gamma}$
γ		$\frac{\alpha'_1 + \alpha'_3}{2}$
0.00000E-99		0.00000E-99
1.00000E-01		-3.74756E-01
1.50000E-01		-4.64269E-01
2.00000E-01		-5.43744E-01
2.50000E-01		-6.18314E-01
3.00000E-01		-6.90960E-01
3.50000E-01		-7.63793E-01
4.00000E-01		-8.37974E-01
4.50000E-01		-9.12627E-01
5.00000E-01		-9.84745E-01
5.50000E-01		-1.05114E-00
6.00000E-01		-1.11035E-00
6.50000E-01		-1.16280E-00
7.00000E-01		-1.21006E-00
7.50000E-01		-1.25400E-00
8.00000E-01		-1.29637E-00
8.50000E-01		-1.33858E-00
9.00000E-01		-1.38177E-00
9.50000E-01		-1.42677E-00
9.52000E-01		-1.42862E-00
9.54000E-01		-1.43047E-00
9.56000E-01		-1.43233E-00
9.58000E-01		-1.43419E-00
9.60000E-01		-1.43605E-00
9.62000E-01		-1.43792E-00
9.64000E-01		-1.43979E-00
9.66000E-01		-1.44167E-00
9.68000E-01		-1.44355E-00
9.70000E-01		-1.44544E-00
9.72000E-01		-1.44733E-00
9.74000E-01		-1.44922E-00
9.76000E-01		-1.45112E-00
9.78000E-01		-1.45302E-00
9.80000E-01		-1.45493E-00
9.82000E-01		-1.45684E-00
9.84000E-01		-1.45875E-00
9.86000E-01		-1.46067E-00
9.88000E-01		-1.46260E-00
9.90000E-01		-1.46453E-00
9.92000E-01		-1.46647E-00
9.94000E-01		-1.46840E-00
9.96000E-01		-1.47035E-00
9.98000E-01		-1.47229E-00
9.99000E-01		-1.47326E-00
1.00000E-00		-1.47425E-00

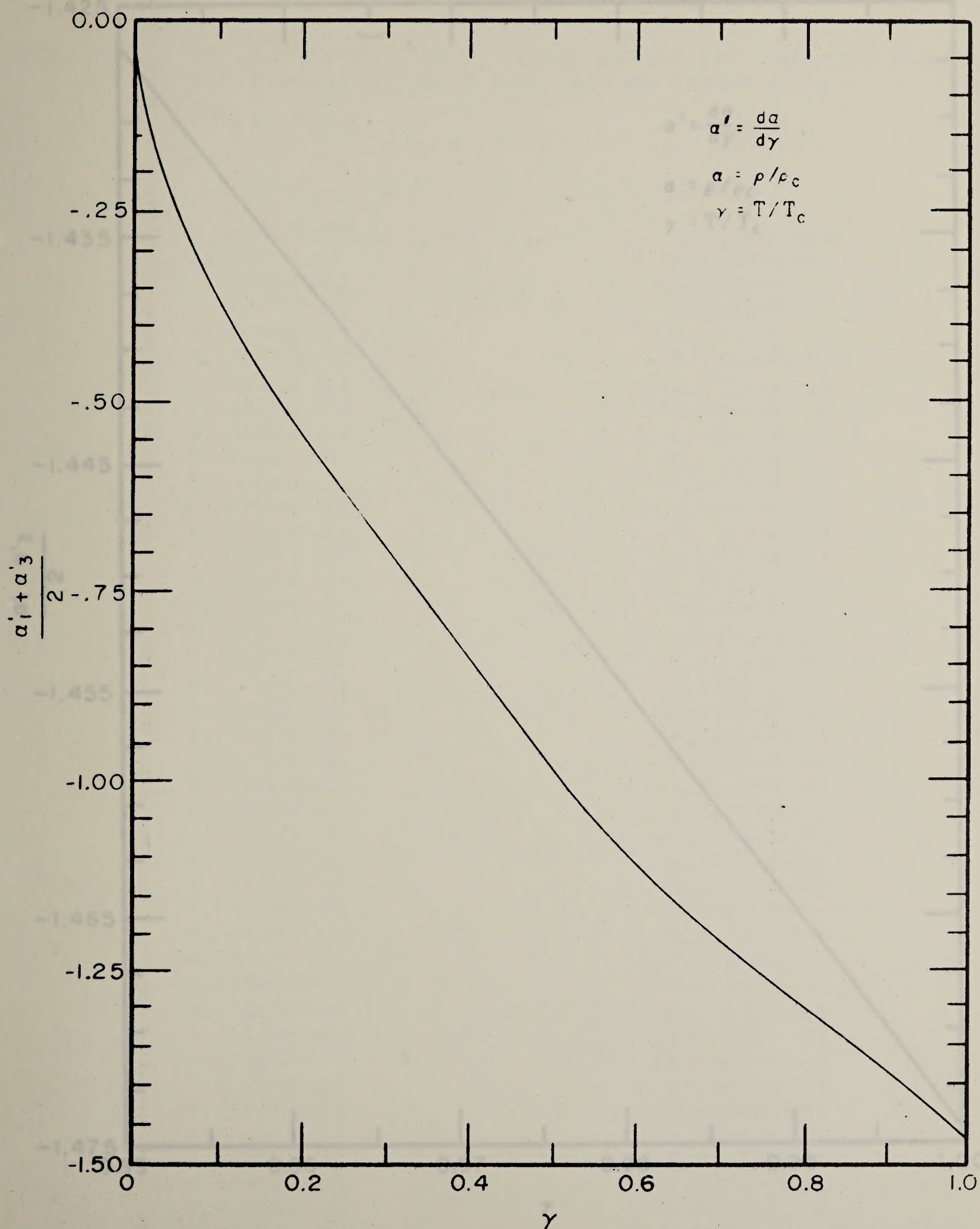


FIGURE 27.—Redlich-Kwong Fluid, Temperature Coefficient of the Rectilinear Diameter as a Function of Temperature.

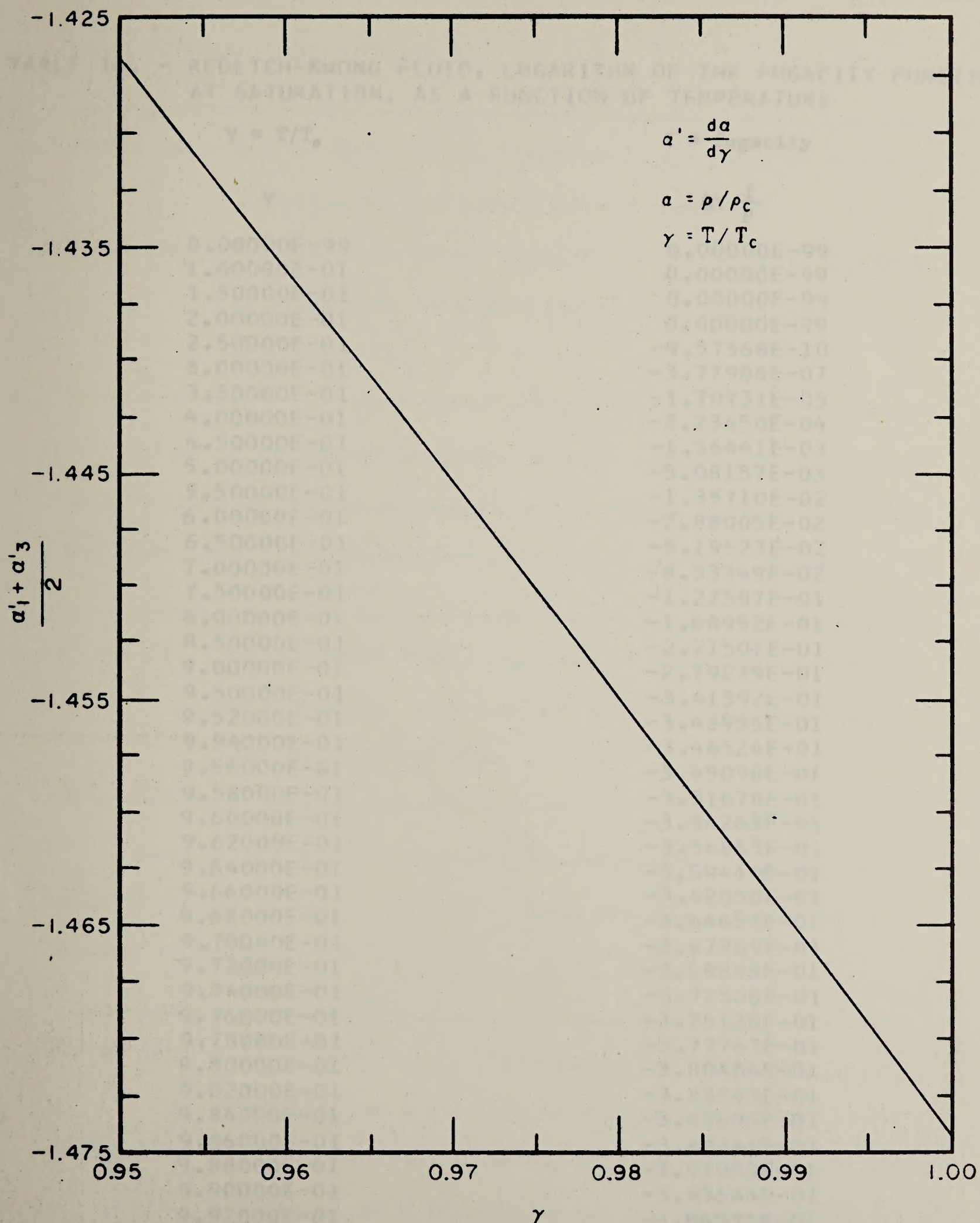


FIGURE 28. - Redlich-Kwong Fluid, Temperature Coefficient of the Rectilinear Diameter as a Function of Temperature Near the Critical Point.

TABLE 16. - REDLICH-KWONG FLUID, LOGARITHM OF THE FUGACITY FUNCTION, AT SATURATION, AS A FUNCTION OF TEMPERATURE

$\gamma = T/T_c$	$f = \text{fugacity}$
γ	$\ln \frac{f}{P}$
0.00000E-99	0.00000E-99
1.00000E-01	0.00000E-99
1.50000E-01	0.00000E-99
2.00000E-01	0.00000E-99
2.50000E-01	-9.57368E-10
3.00000E-01	-3.77908E-07
3.50000E-01	-1.70731E-05
4.00000E-01	-2.23450E-04
4.50000E-01	-1.36441E-03
5.00000E-01	-5.08157E-03
5.50000E-01	-1.35710E-02
6.00000E-01	-2.88005E-02
6.50000E-01	-5.19523E-02
7.00000E-01	-8.33349E-02
7.50000E-01	-1.22587E-01
8.00000E-01	-1.68952E-01
8.50000E-01	-2.21501E-01
9.00000E-01	-2.79279E-01
9.50000E-01	-3.41392E-01
9.52000E-01	-3.43955E-01
9.54000E-01	-3.46524E-01
9.56000E-01	-3.49098E-01
9.58000E-01	-3.51678E-01
9.60000E-01	-3.54263E-01
9.62000E-01	-3.56853E-01
9.64000E-01	-3.59449E-01
9.66000E-01	-3.62050E-01
9.68000E-01	-3.64657E-01
9.70000E-01	-3.67269E-01
9.72000E-01	-3.69886E-01
9.74000E-01	-3.72508E-01
9.76000E-01	-3.75135E-01
9.78000E-01	-3.77767E-01
9.80000E-01	-3.80404E-01
9.82000E-01	-3.83047E-01
9.84000E-01	-3.85694E-01
9.86000E-01	-3.88346E-01
9.88000E-01	-3.91003E-01
9.90000E-01	-3.93664E-01
9.92000E-01	-3.96331E-01
9.94000E-01	-3.99002E-01
9.96000E-01	-4.01677E-01
9.98000E-01	-4.04358E-01
9.99000E-01	-4.05700E-01
1.00000E-00	-4.07043E-01

illustrated in figures 29 and 30.

FIGURE 29. - Redlich-Kwong fluid, logarithm of the fugacity function, at saturation, as a function of temperature.

FIGURE 30. - Redlich-Kwong fluid, logarithm of the fugacity function, at saturation, as a function of temperature near the critical point.

Values of the logarithm of the fugacity function, at saturation, as a function of reciprocal temperature are given in table 17. These same data, near the critical point, are illustrated in figure 31.

FIGURE 31. - Redlich-Kwong fluid, logarithm of the fugacity function, at saturation, as a function of reciprocal temperature near the critical point.

Values of the fugacity function, at saturation, as a function of temperature are listed in table 18. These data are illustrated in figures 32 and 33.

FIGURE 32. - Redlich-Kwong fluid, the fugacity function, at saturation, as a function of the temperature.

FIGURE 33. - Redlich-Kwong fluid, the fugacity function, at saturation, as a function of the temperature near the critical point.

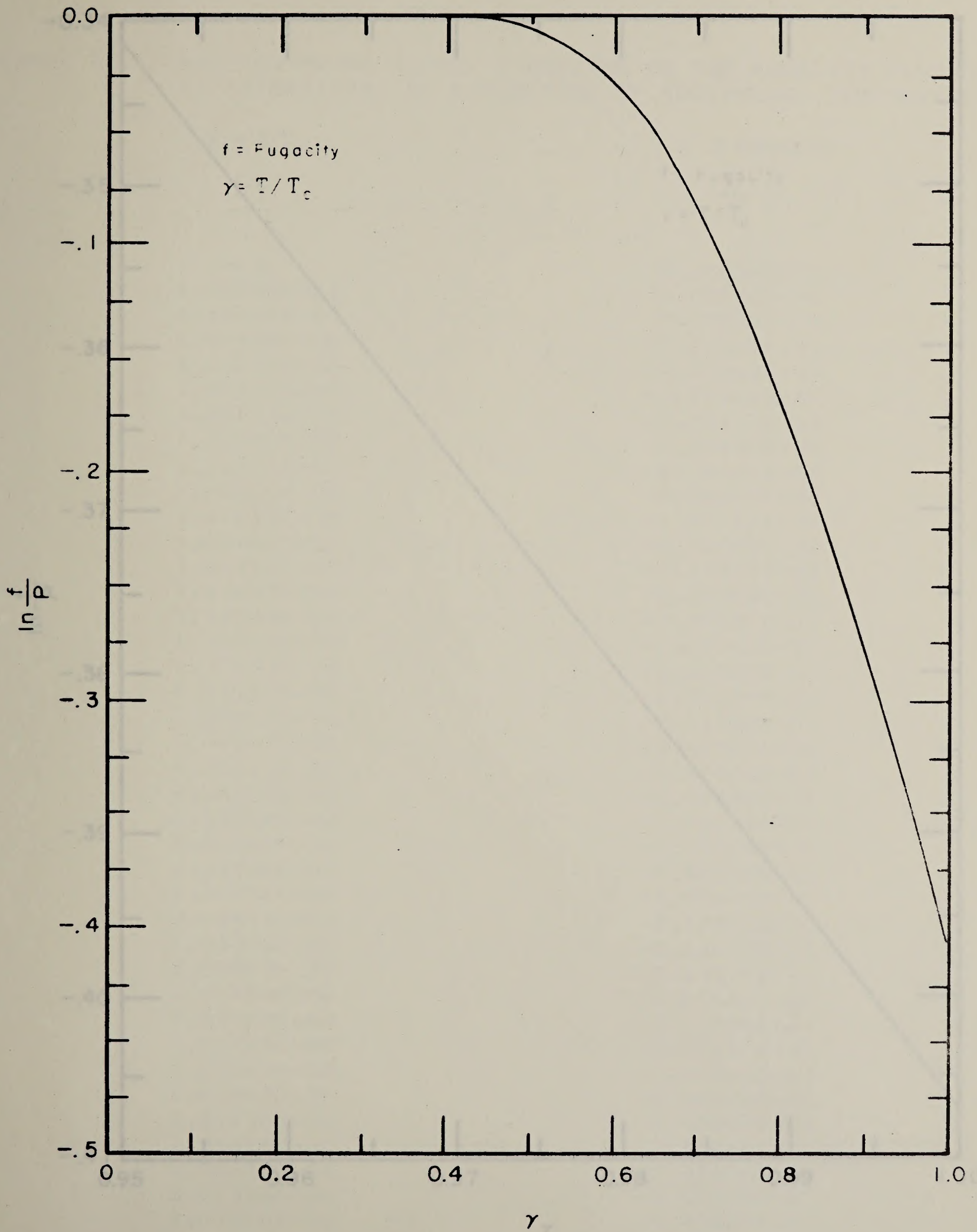


FIGURE 29. - Redlich-Kwong Fluid, Logarithm of the Fugacity Function, at Saturation, as a Function of Temperature.

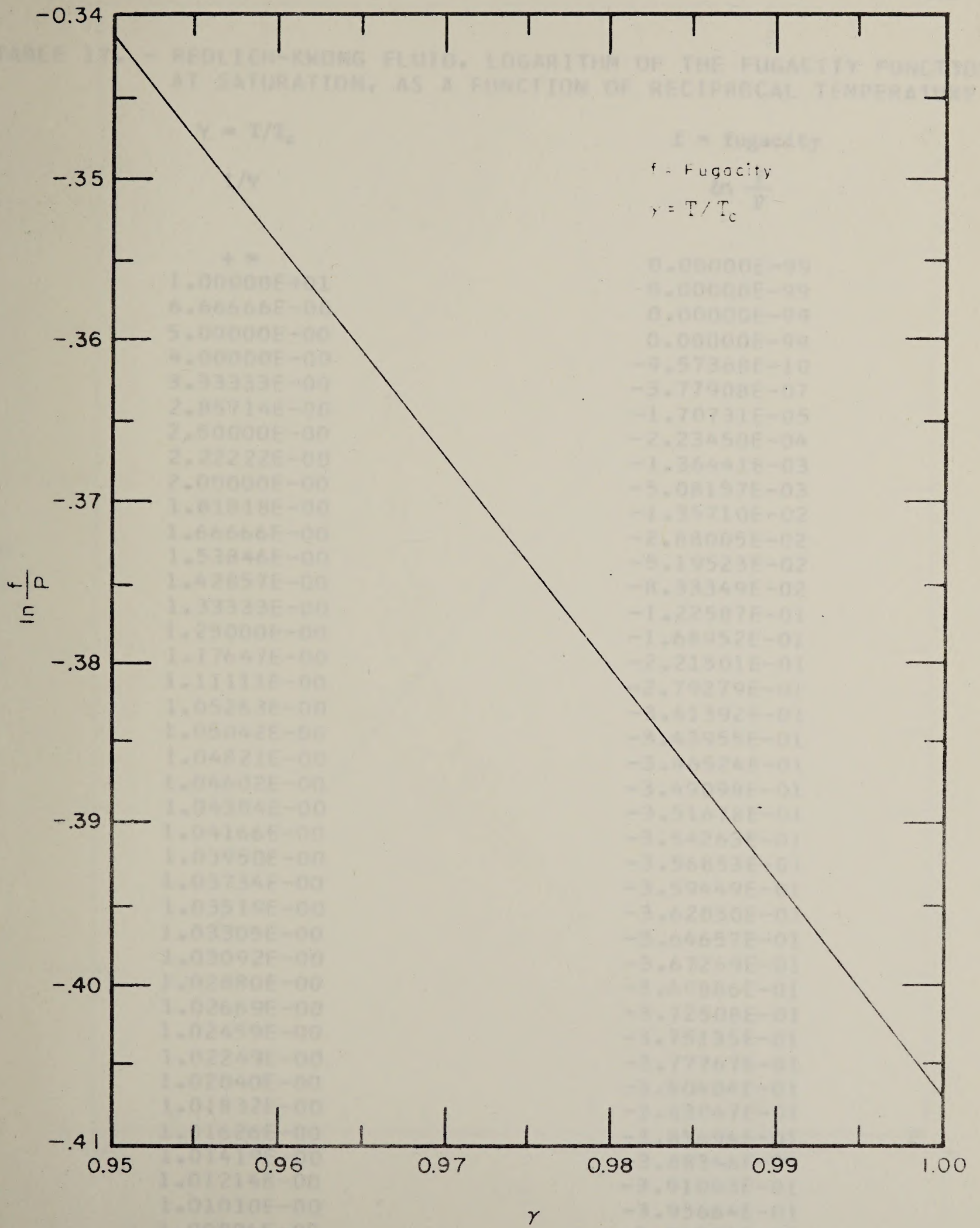


FIGURE 30.- Redlich-Kwong Fluid, Logarithm of the Fugacity Function, at Saturation, as a Function of Temperature Near the Critical Point.

TABLE 17. - REDLICH-KWONG FLUID, LOGARITHM OF THE FUGACITY FUNCTION, AT SATURATION, AS A FUNCTION OF RECIPROCAL TEMPERATURE

$\gamma = T/T_c$	$f = \text{fugacity}$
$1/\gamma$	$\ln \frac{f}{P}$
$+\infty$	0.00000E-99
1.00000E+01	0.00000E-99
6.66666E-00	0.00000E-99
5.00000E-00	0.00000E-99
4.00000E-00	-9.57368E-10
3.33333E-00	-3.77908E-07
2.85714E-00	-1.70731E-05
2.50000E-00	-2.23450E-04
2.22222E-00	-1.36441E-03
2.00000E-00	-5.08157E-03
1.81818E-00	-1.35710E-02
1.66666E-00	-2.88005E-02
1.53846E-00	-5.19523E-02
1.42857E-00	-8.33349E-02
1.33333E-00	-1.22587E-01
1.25000E-00	-1.68952E-01
1.17647E-00	-2.21501E-01
1.11111E-00	-2.79279E-01
1.05263E-00	-3.41392E-01
1.05042E-00	-3.43955E-01
1.04821E-00	-3.46524E-01
1.04602E-00	-3.49098E-01
1.04384E-00	-3.51678E-01
1.04166E-00	-3.54263E-01
1.03950E-00	-3.56853E-01
1.03734E-00	-3.59449E-01
1.03519E-00	-3.62050E-01
1.03305E-00	-3.64657E-01
1.03092E-00	-3.67269E-01
1.02880E-00	-3.69886E-01
1.02669E-00	-3.72508E-01
1.02459E-00	-3.75135E-01
1.02249E-00	-3.77767E-01
1.02040E-00	-3.80404E-01
1.01832E-00	-3.83047E-01
1.01626E-00	-3.85694E-01
1.01419E-00	-3.88346E-01
1.01214E-00	-3.91003E-01
1.01010E-00	-3.93664E-01
1.00806E-00	-3.96331E-01
1.00603E-00	-3.99002E-01
1.00401E-00	-4.01677E-01
1.00200E-00	-4.04358E-01
1.00100E-00	-4.05700E-01
1.00000E-00	-4.07043E-01

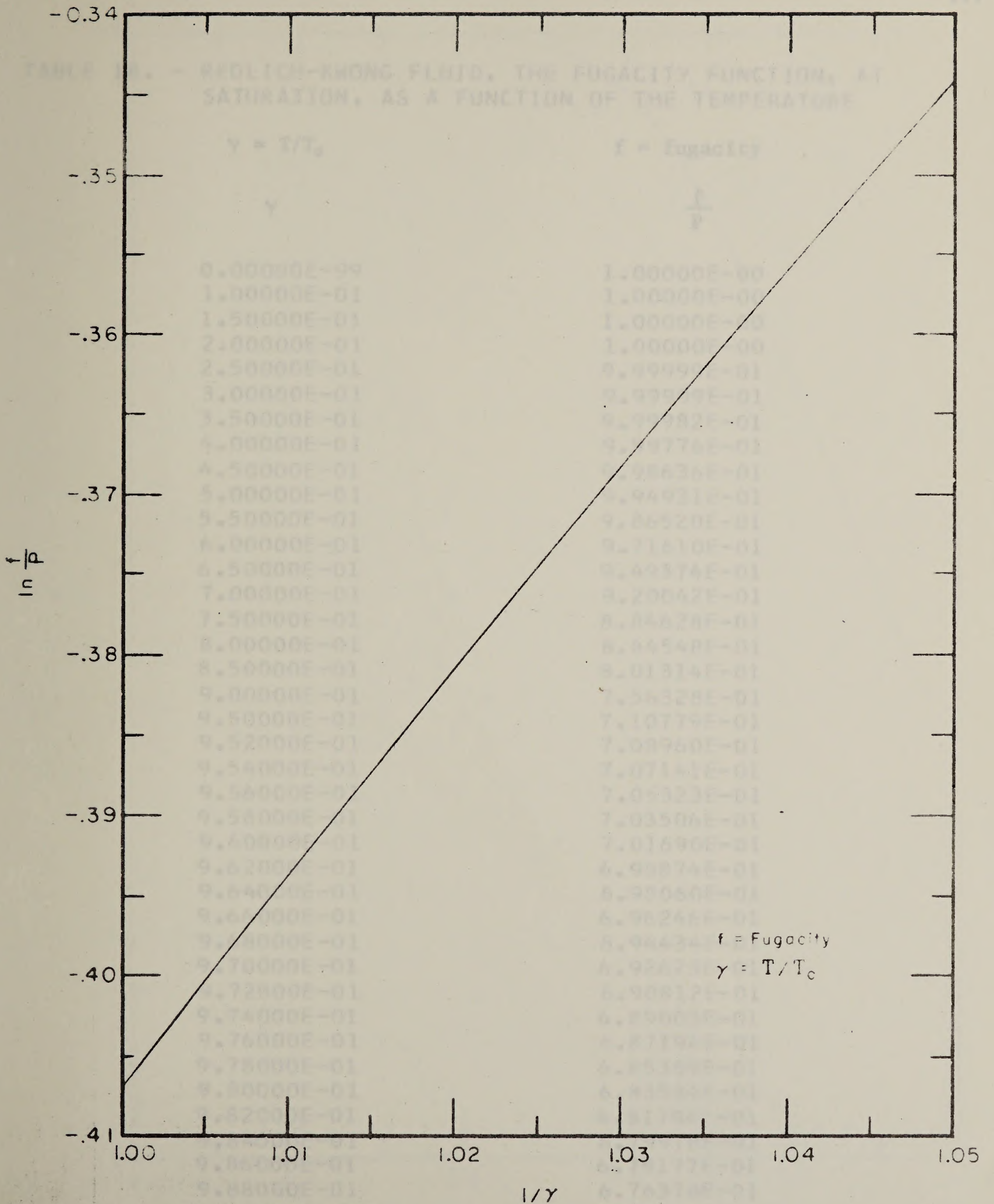


FIGURE 31. - Redlich-Kwong Fluid, Logarithm of the Fugacity Function, at Saturation, as a Function of Reciprocal Temperature Near the Critical Point.

TABLE 18. - REDLICH-KWONG FLUID, THE FUGACITY FUNCTION, AT SATURATION, AS A FUNCTION OF THE TEMPERATURE

$\gamma = T/T_c$	$f = \text{fugacity}$
γ	$\frac{f}{P}$
0.00000E-99	1.00000E-00
1.00000E-01	1.00000E-00
1.50000E-01	1.00000E-00
2.00000E-01	1.00000E-00
2.50000E-01	9.99999E-01
3.00000E-01	9.99999E-01
3.50000E-01	9.99982E-01
4.00000E-01	9.99776E-01
4.50000E-01	9.98636E-01
5.00000E-01	9.94931E-01
5.50000E-01	9.86520E-01
6.00000E-01	9.71610E-01
6.50000E-01	9.49374E-01
7.00000E-01	9.20042E-01
7.50000E-01	8.84628E-01
8.00000E-01	8.44548E-01
8.50000E-01	8.01314E-01
9.00000E-01	7.56328E-01
9.50000E-01	7.10779E-01
9.52000E-01	7.08960E-01
9.54000E-01	7.07141E-01
9.56000E-01	7.05323E-01
9.58000E-01	7.03506E-01
9.60000E-01	7.01690E-01
9.62000E-01	6.99874E-01
9.64000E-01	6.98060E-01
9.66000E-01	6.96246E-01
9.68000E-01	6.94434E-01
9.70000E-01	6.92623E-01
9.72000E-01	6.90812E-01
9.74000E-01	6.89003E-01
9.76000E-01	6.87196E-01
9.78000E-01	6.85389E-01
9.80000E-01	6.83584E-01
9.82000E-01	6.81780E-01
9.84000E-01	6.79978E-01
9.86000E-01	6.78177E-01
9.88000E-01	6.76378E-01
9.90000E-01	6.74580E-01
9.92000E-01	6.72783E-01
9.94000E-01	6.70989E-01
9.96000E-01	6.69196E-01
9.98000E-01	6.67404E-01
9.99000E-01	6.66509E-01
1.00000E-00	6.65615E-01

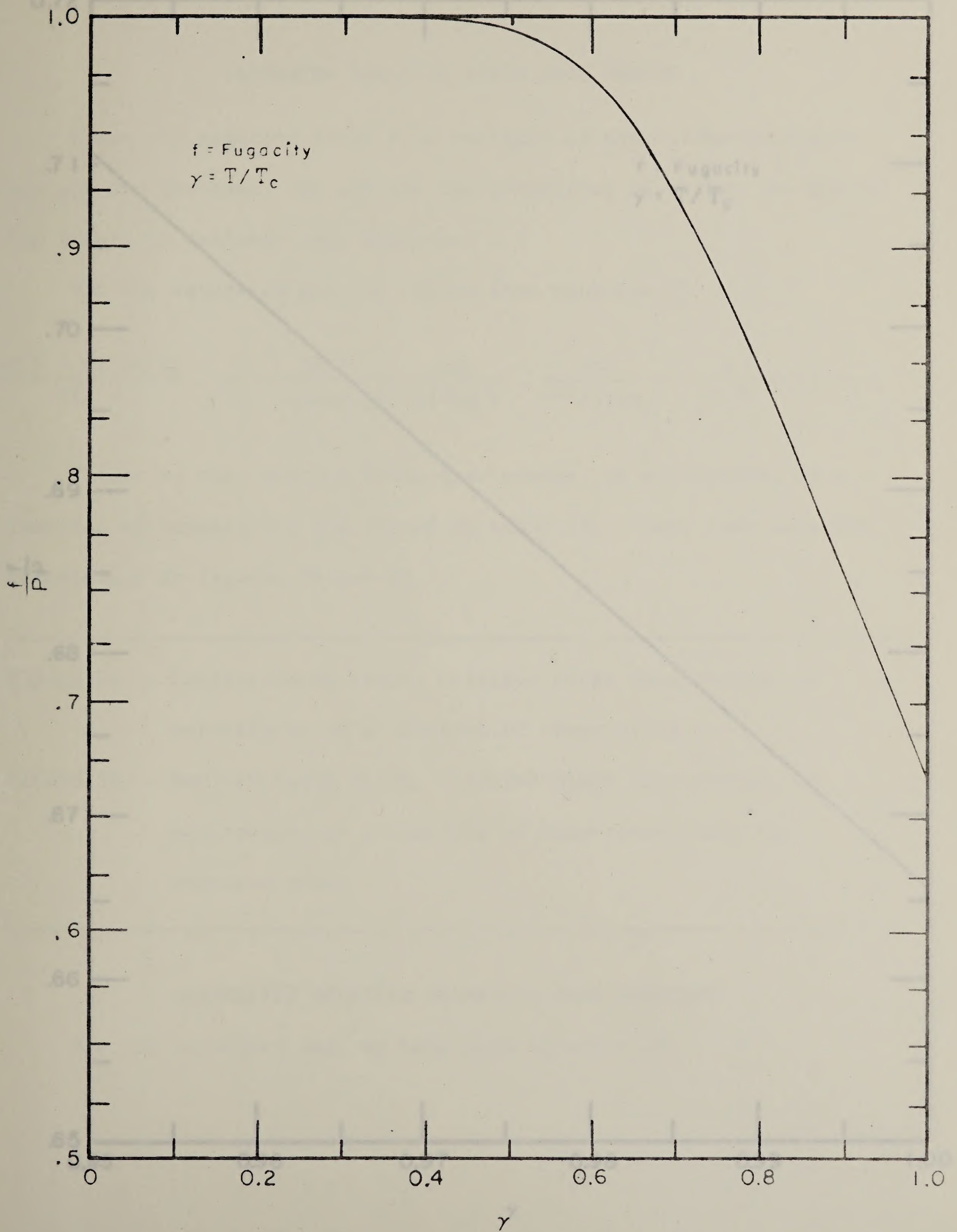


FIGURE 32. — Redlich-Kwong Fluid, the Fugacity Function, at Saturation, as a Function of the Temperature.

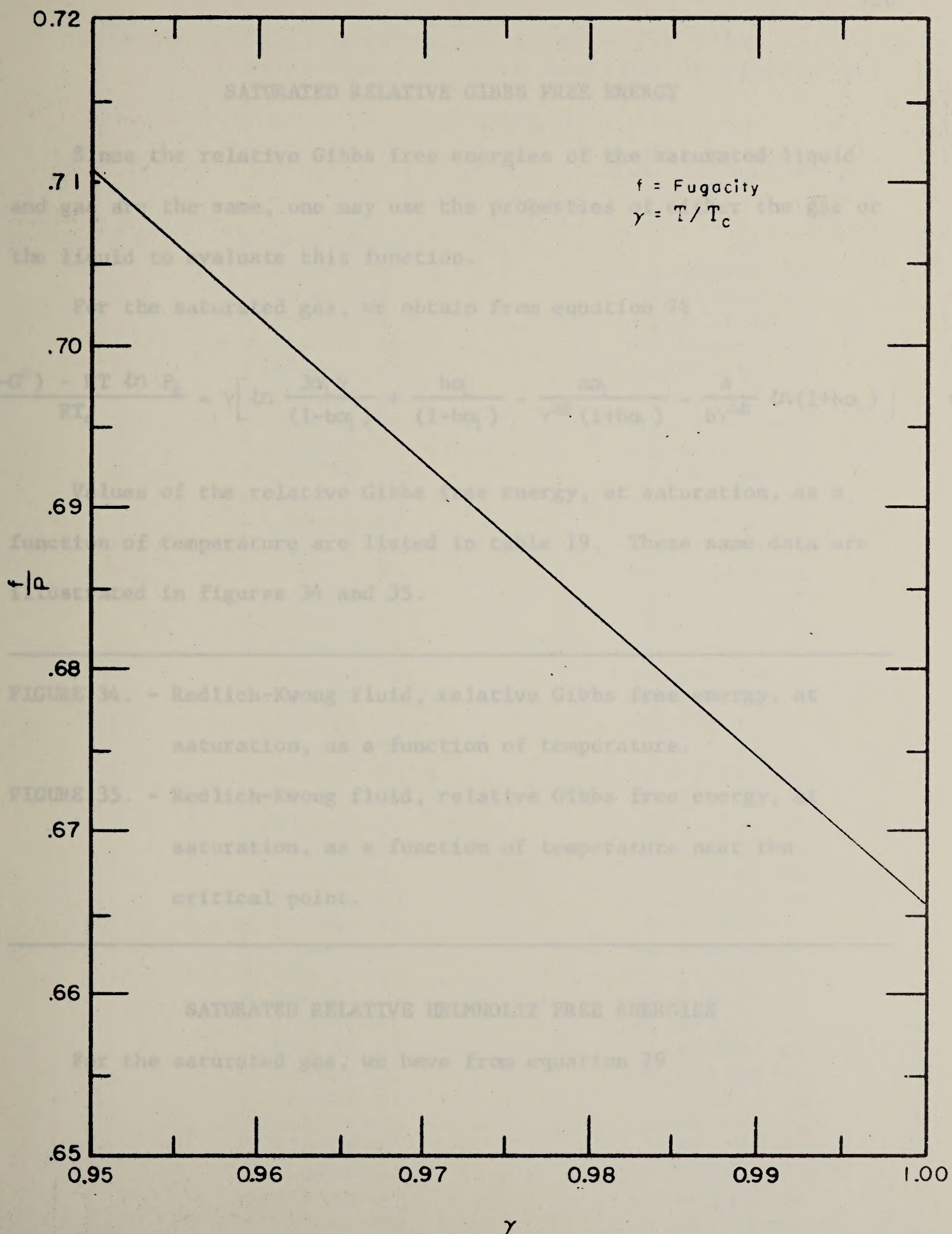


FIGURE 33. - Redlich-Kwong Fluid, the Fugacity Function, at Saturation, as a Function of the Temperature Near the Critical Point.

SATURATED RELATIVE GIBBS FREE ENERGY

Since the relative Gibbs free energies of the saturated liquid and gas are the same, one may use the properties of either the gas or the liquid to evaluate this function.

For the saturated gas, we obtain from equation 74

$$\frac{(G-G^0) - RT \ln P_c}{RT_c} = \gamma \left[\ln \frac{3\alpha_1 \gamma}{(1-b\alpha_1)} + \frac{b\alpha_1}{(1-b\alpha_1)} - \frac{a\alpha_1}{\gamma^{3/2} (1+b\alpha_1)} - \frac{a}{b\gamma^{3/2}} \ln(1+b\alpha_1) \right] \quad (221)$$

Values of the relative Gibbs free energy, at saturation, as a function of temperature are listed in table 19. These same data are illustrated in figures 34 and 35.

FIGURE 34. - Redlich-Kwong fluid, relative Gibbs free energy, at saturation, as a function of temperature.

FIGURE 35. - Redlich-Kwong fluid, relative Gibbs free energy, at saturation, as a function of temperature near the critical point.

SATURATED RELATIVE HELMHOLTZ FREE ENERGIES

For the saturated gas, we have from equation 79

TABLE 19. - REDLICH-KWONG FLUID, RELATIVE GIBBS FREE ENERGY, AT SATURATION, AS A FUNCTION OF TEMPERATURE

$$\gamma = T/T_c$$

γ	$\frac{(G-G^0) - RT \ln P_c}{RT_c}$
0.00000E-00	- ∞
1.00000E-01	-1.03658E+01
1.50000E-01	-8.18836E-00
2.00000E-01	-6.82211E-00
2.50000E-01	-5.83926E-00
3.00000E-01	-5.07444E-00
3.50000E-01	-4.44845E-00
4.00000E-01	-3.91795E-00
4.50000E-01	-3.45704E-00
5.00000E-01	-3.04910E-00
5.50000E-01	-2.68287E-00
6.00000E-01	-2.35035E-00
6.50000E-01	-2.04560E-00
7.00000E-01	-1.76408E-00
7.50000E-01	-1.50225E-00
8.00000E-01	-1.25730E-00
8.50000E-01	-1.02697E-00
9.00000E-01	-8.09445E-01
9.50000E-01	-6.03210E-01
9.52000E-01	-5.95177E-01
9.54000E-01	-5.87161E-01
9.56000E-01	-5.79160E-01
9.58000E-01	-5.71175E-01
9.60000E-01	-5.63207E-01
9.62000E-01	-5.55253E-01
9.64000E-01	-5.47316E-01
9.66000E-01	-5.39394E-01
9.68000E-01	-5.31487E-01
9.70000E-01	-5.23596E-01
9.72000E-01	-5.15721E-01
9.74000E-01	-5.07860E-01
9.76000E-01	-5.00015E-01
9.78000E-01	-4.92186E-01
9.80000E-01	-4.84371E-01
9.82000E-01	-4.76571E-01
9.84000E-01	-4.68787E-01
9.86000E-01	-4.61017E-01
9.88000E-01	-4.53262E-01
9.90000E-01	-4.45522E-01
9.92000E-01	-4.37797E-01
9.94000E-01	-4.30087E-01
9.96000E-01	-4.22391E-01
9.98000E-01	-4.14710E-01
9.99000E-01	-4.10874E-01
1.00000E-00	-4.07043E-01

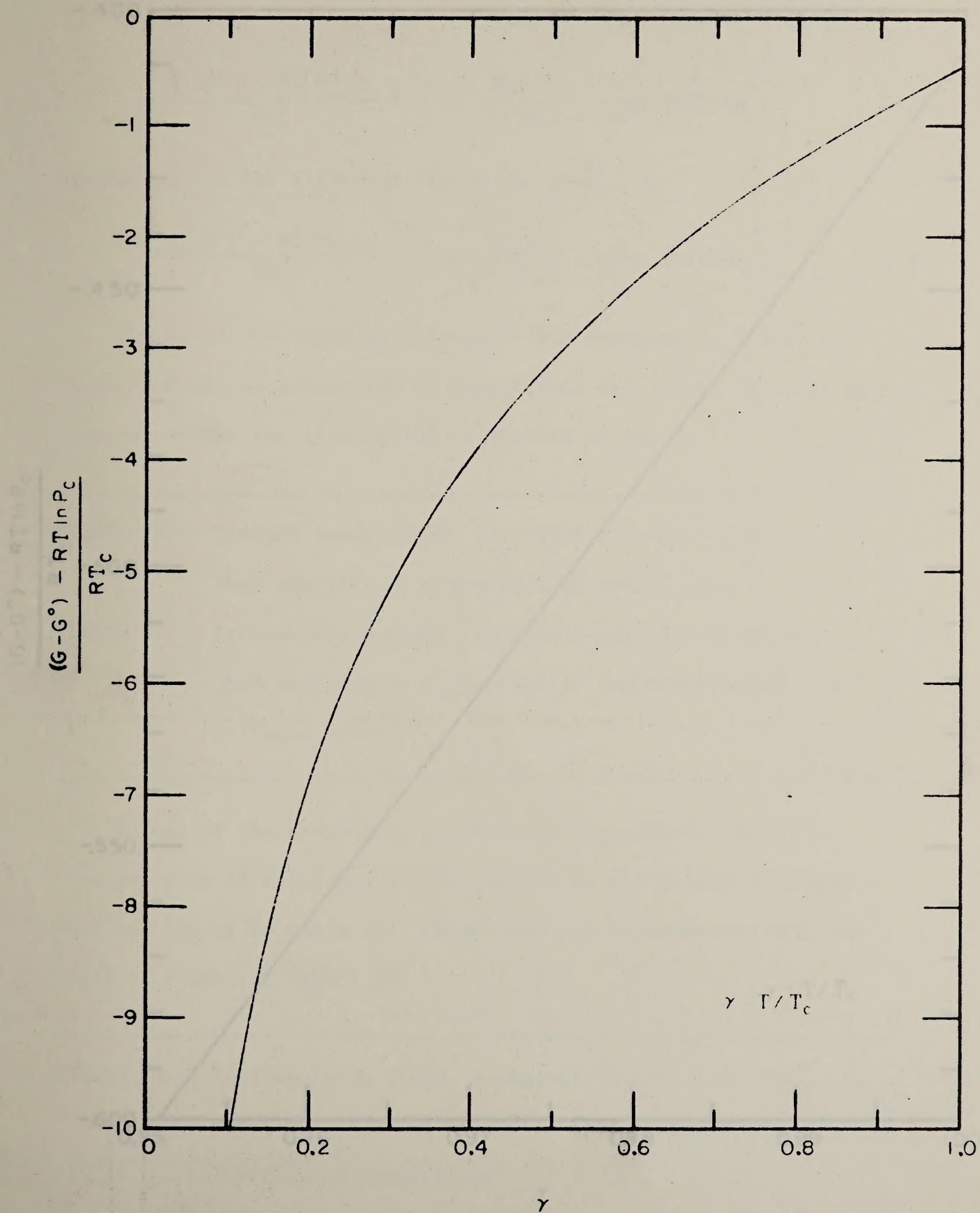


FIGURE 34.- Redlich - Kwong Fluid, Relative Gibbs Free Energy, at Saturation, as a Function of Temperature.

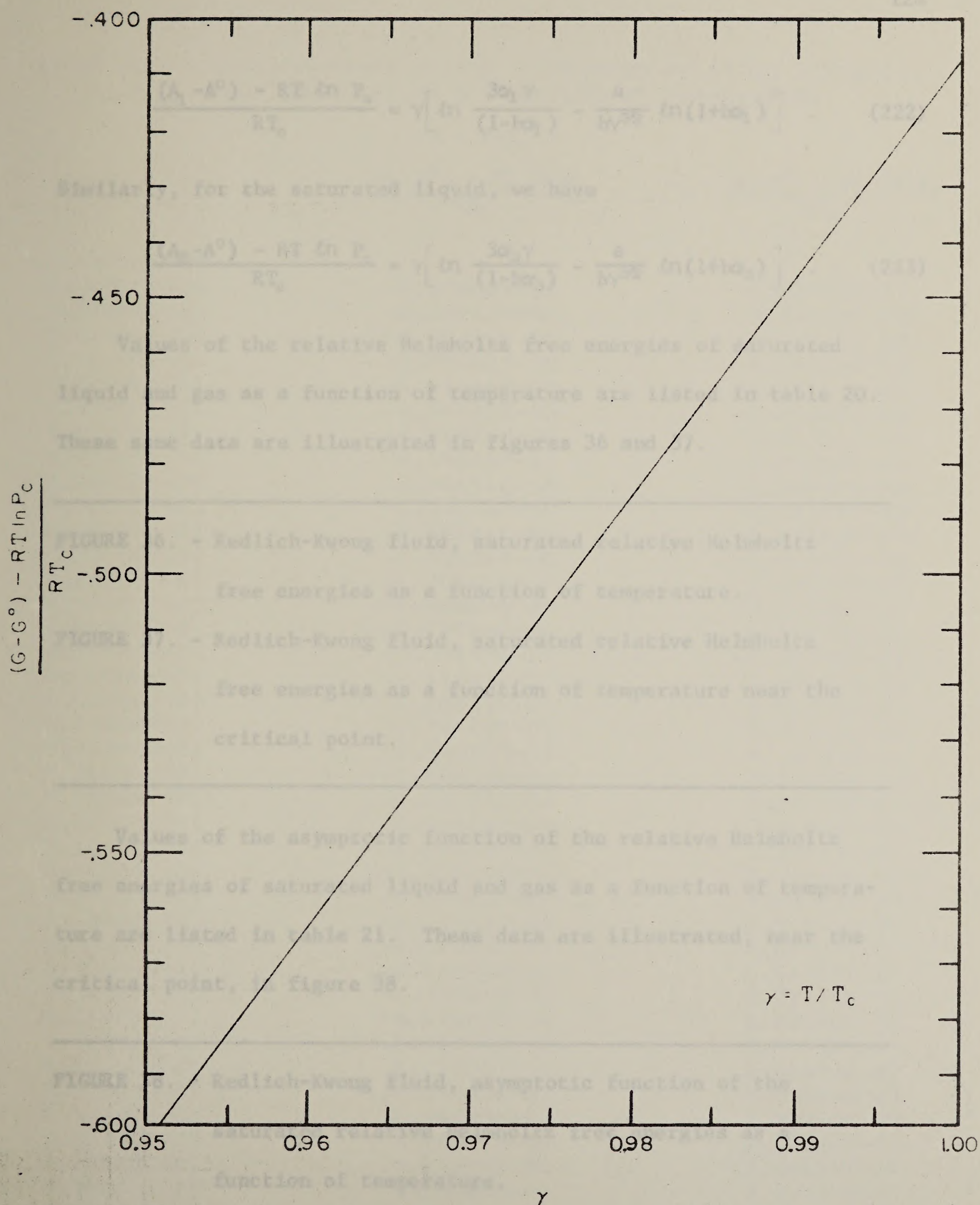


FIGURE 35.—Redlich - Kwong Fluid, Relative Gibbs Free Energy, at Saturation, as a Function of Temperature Near the Critical Point.

$$\frac{(A_1 - A^0) - RT \ln P_c}{RT_c} = \gamma \left[\ln \frac{3\alpha_1 \gamma}{(1 - b\alpha_1)} - \frac{a}{b\gamma^{3/2}} \ln(1 + b\alpha_1) \right] \quad (222)$$

Similarly, for the saturated liquid, we have

$$\frac{(A_3 - A^0) - RT \ln P_c}{RT_c} = \gamma \left[\ln \frac{3\alpha_3 \gamma}{(1 - b\alpha_3)} - \frac{a}{b\gamma^{3/2}} \ln(1 + b\alpha_3) \right] \quad (223)$$

Values of the relative Helmholtz free energies of saturated liquid and gas as a function of temperature are listed in table 20. These same data are illustrated in figures 36 and 37.

FIGURE 36. - Redlich-Kwong fluid, saturated relative Helmholtz free energies as a function of temperature.

FIGURE 37. - Redlich-Kwong fluid, saturated relative Helmholtz free energies as a function of temperature near the critical point.

Values of the asymptotic function of the relative Helmholtz free energies of saturated liquid and gas as a function of temperature are listed in table 21. These data are illustrated, near the critical point, in figure 38.

FIGURE 38. - Redlich-Kwong fluid, asymptotic function of the saturated relative Helmholtz free energies as a function of temperature.

TABLE 20. - REDLICH-KWONG FLUID, SATURATED RELATIVE HELMHOLTZ FREE ENERGIES AS A FUNCTION OF TEMPERATURE

γ	$\gamma = T/T_c$	
	$\frac{(A_1 - A^0) - RT \ln P_c}{RT_c}$	$\frac{(A_3 - A^0) - RT \ln P_c}{RT_c}$
0.00000E-99	- ∞	- ∞
1.00000E-01	-1.03658E+01	-1.02658E+01
1.50000E-01	-8.18836E-00	-8.03836E-00
2.00000E-01	-6.82211E-00	-6.62211E-00
2.50000E-01	-5.83926E-00	-5.58926E-00
3.00000E-01	-5.07444E-00	-4.77444E-00
3.50000E-01	-4.44844E-00	-4.09845E-00
4.00000E-01	-3.91786E-00	-3.51796E-00
4.50000E-01	-3.45642E-00	-3.00708E-00
5.00000E-01	-3.04655E-00	-2.54933E-00
5.50000E-01	-2.67536E-00	-2.13369E-00
6.00000E-01	-2.33284E-00	-1.75261E-00
6.50000E-01	-2.01101E-00	-1.40080E-00
7.00000E-01	-1.70341E-00	-1.07464E-00
7.50000E-01	-1.40464E-00	-7.71784E-01
8.00000E-01	-1.10988E-00	-4.91072E-01
8.50000E-01	-8.14177E-01	-2.32792E-01
9.00000E-01	-5.11143E-01	3.40493E-04
9.50000E-01	-1.88431E-01	1.98912E-01
9.52000E-01	-1.74729E-01	2.05786E-01
9.54000E-01	-1.60932E-01	2.12547E-01
9.56000E-01	-1.47036E-01	2.19188E-01
9.58000E-01	-1.33033E-01	2.25703E-01
9.60000E-01	-1.18916E-01	2.32084E-01
9.62000E-01	-1.04675E-01	2.38322E-01
9.64000E-01	-9.03017E-02	2.44408E-01
9.66000E-01	-7.57842E-02	2.50331E-01
9.68000E-01	-6.11101E-02	2.56079E-01
9.70000E-01	-4.62646E-02	2.61637E-01
9.72000E-01	-3.12308E-02	2.66987E-01
9.74000E-01	-1.59885E-02	2.72111E-01
9.76000E-01	-5.13606E-04	2.76983E-01
9.78000E-01	1.52230E-02	2.81576E-01
9.80000E-01	3.12570E-02	2.85853E-01
9.82000E-01	4.76335E-02	2.89769E-01
9.84000E-01	6.44100E-02	2.93268E-01
9.86000E-01	8.16627E-02	2.96272E-01
9.88000E-01	9.94958E-02	2.98679E-01
9.90000E-01	1.18059E-01	3.00337E-01
9.92000E-01	1.37582E-01	3.01018E-01
9.94000E-01	1.58450E-01	3.00338E-01
9.96000E-01	1.81411E-01	2.97546E-01
9.98000E-01	2.08395E-01	2.90715E-01
9.99000E-01	2.25450E-01	2.83730E-01
1.00000E-00	2.59623E-01	2.59623E-01

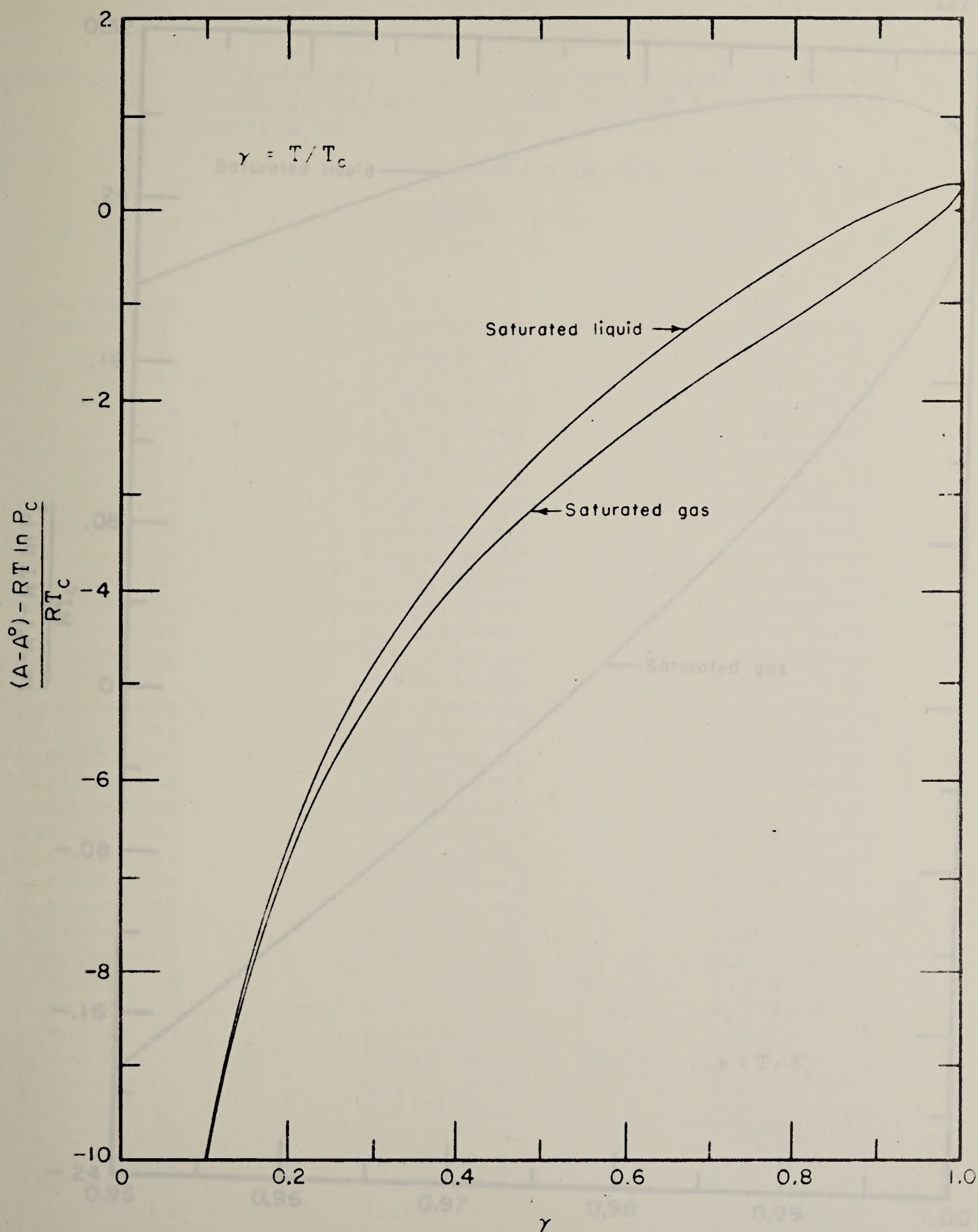


FIGURE 36.- Redlich - Kwong Fluid, Saturated Relative Helmholtz Free Energies as a Function of Temperature.

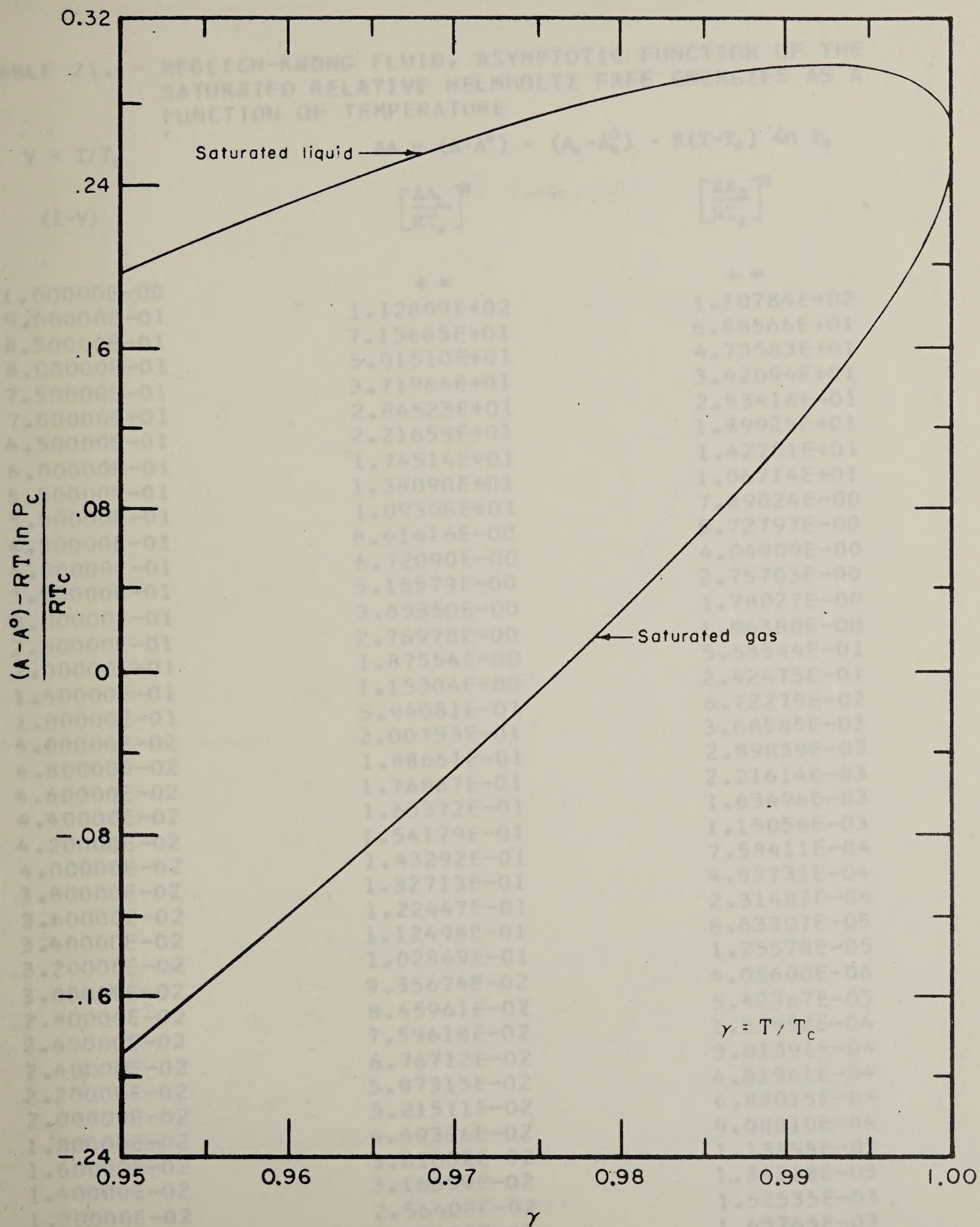


FIGURE 37.—Redlich-Kwong Fluid, Saturated Relative Helmholtz Free Energies as a Function of Temperature Near the Critical Point.

TABLE 21. - REDLICH-KWONG FLUID, ASYMPTOTIC FUNCTION OF THE SATURATED RELATIVE HELMHOLTZ FREE ENERGIES AS A FUNCTION OF TEMPERATURE

$\gamma = T/T_c$	$\Delta A = (A - A^0) - (A_c - A_c^0) - R(T - T_c) \ln P_c$	
$(1 - \gamma)$	$\left[\frac{\Delta A_1}{RT_c} \right]^2$	$\left[\frac{\Delta A_3}{RT_c} \right]^2$
1.00000E-00	+ ∞	+ ∞
9.00000E-01	1.12899E+02	1.10784E+02
8.50000E-01	7.13685E+01	6.88566E+01
8.00000E-01	5.01510E+01	4.73583E+01
7.50000E-01	3.71964E+01	3.42094E+01
7.00000E-01	2.84523E+01	2.53418E+01
6.50000E-01	2.21659E+01	1.89928E+01
6.00000E-01	1.74514E+01	1.42701E+01
5.50000E-01	1.38090E+01	1.06714E+01
5.00000E-01	1.09308E+01	7.89024E-00
4.50000E-01	8.61416E-00	5.72797E-00
4.00000E-01	6.72090E-00	4.04909E-00
3.50000E-01	5.15579E-00	2.75703E-00
3.00000E-01	3.85350E-00	1.78027E-00
2.50000E-01	2.76978E-00	1.06380E-00
2.00000E-01	1.87554E-00	5.63544E-01
1.50000E-01	1.15304E-00	2.42473E-01
1.00000E-01	5.94081E-01	6.72275E-02
5.00000E-02	2.00753E-01	3.68585E-03
4.80000E-02	1.88661E-01	2.89839E-03
4.60000E-02	1.76867E-01	2.21614E-03
4.40000E-02	1.65372E-01	1.63496E-03
4.20000E-02	1.54179E-01	1.15056E-03
4.00000E-02	1.43292E-01	7.58411E-04
3.80000E-02	1.32713E-01	4.53731E-04
3.60000E-02	1.22447E-01	2.31487E-04
3.40000E-02	1.12498E-01	8.63307E-05
3.20000E-02	1.02869E-01	1.25578E-05
3.00000E-02	9.35674E-02	4.05600E-06
2.80000E-02	8.45961E-02	5.42367E-05
2.60000E-02	7.59618E-02	1.55952E-04
2.40000E-02	6.76712E-02	3.01391E-04
2.20000E-02	5.97315E-02	4.81941E-04
2.00000E-02	5.21511E-02	6.88015E-04
1.80000E-02	4.49396E-02	9.08810E-04
1.60000E-02	3.81082E-02	1.13198E-03
1.40000E-02	3.16699E-02	1.34318E-03
1.20000E-02	2.56408E-02	1.52535E-03
1.00000E-02	2.00403E-02	1.65765E-03
8.00000E-03	1.48939E-02	1.71359E-03
6.00000E-03	1.02360E-02	1.65770E-03
4.00000E-03	6.11706E-03	1.43817E-03
2.00000E-03	2.62430E-03	9.66730E-04
1.00000E-03	1.16778E-03	5.81155E-04
0.00000E-99	0.00000E-99	0.00000E-99

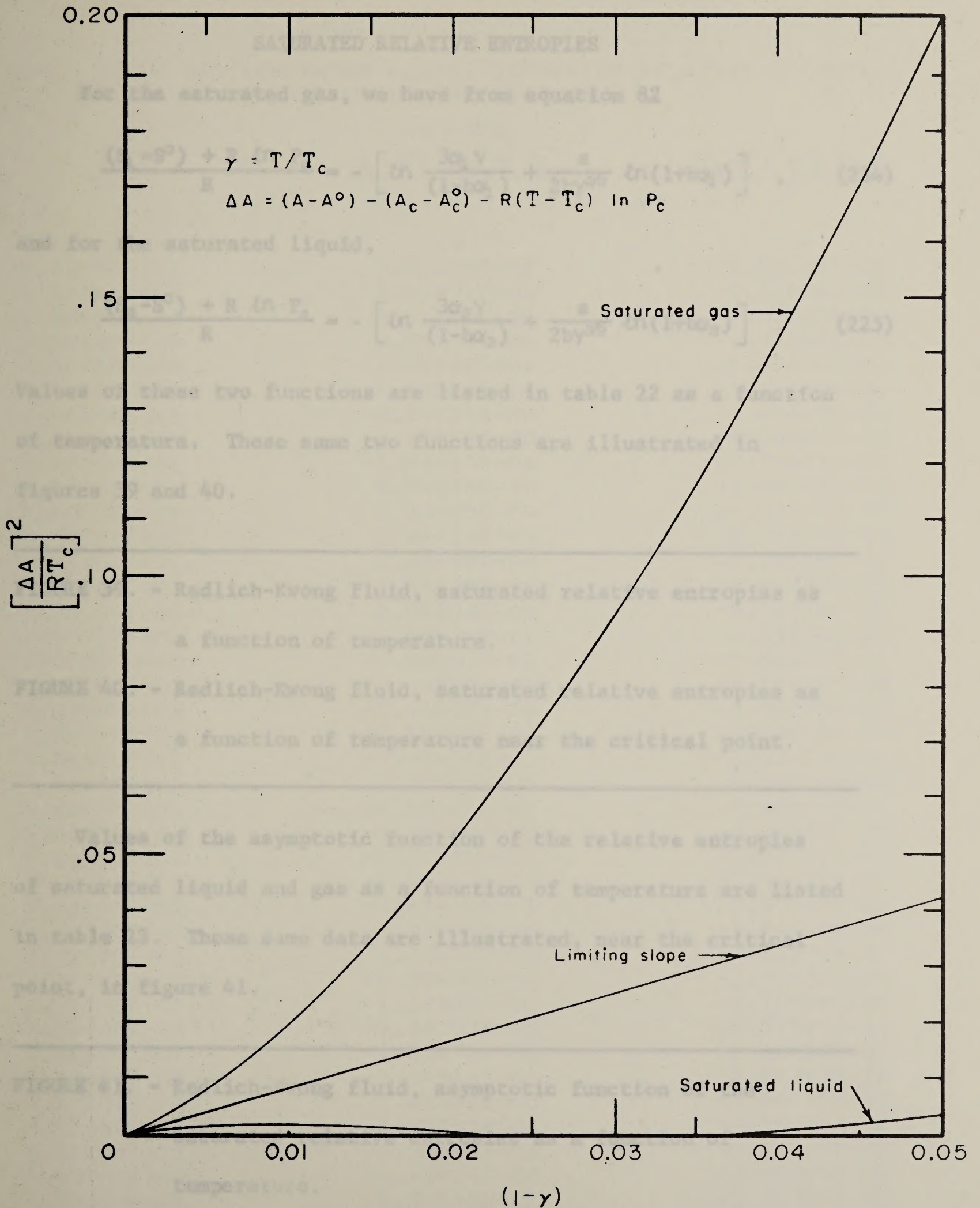


FIGURE 38. - Redlich-Kwong Fluid, Asymptotic Function of the Saturated Relative Helmholtz Free Energies as a Function of Temperature.

SATURATED RELATIVE ENTROPIES

For the saturated gas, we have from equation 82

$$\frac{(S_1 - S^0) + R \ln P_g}{R} = - \left[\ln \frac{3\alpha_1 \gamma}{(1 - b\alpha_1)} + \frac{a}{2b\gamma^{3/2}} \ln(1 + b\alpha_1) \right], \quad (224)$$

and for the saturated liquid,

$$\frac{(S_3 - S^0) + R \ln P_g}{R} = - \left[\ln \frac{3\alpha_3 \gamma}{(1 - b\alpha_3)} + \frac{a}{2b\gamma^{3/2}} \ln(1 + b\alpha_3) \right]. \quad (225)$$

Values of these two functions are listed in table 22 as a function of temperature. These same two functions are illustrated in figures 39 and 40.

FIGURE 39. - Redlich-Kwong fluid, saturated relative entropies as a function of temperature.

FIGURE 40. - Redlich-Kwong fluid, saturated relative entropies as a function of temperature near the critical point.

Values of the asymptotic function of the relative entropies of saturated liquid and gas as a function of temperature are listed in table 23. These same data are illustrated, near the critical point, in figure 41.

FIGURE 41. - Redlich-Kwong fluid, asymptotic function of the saturated relative entropies as a function of temperature.

TABLE 22. - REDLICH-KWONG FLUID, SATURATED RELATIVE ENTROPIES
AS A FUNCTION OF TEMPERATURE

γ	$\gamma = T/T_c$	
	$\frac{(S_1 - S^0) + R \ln P_c}{R}$	$\frac{(S_3 - S^0) + R \ln P_c}{R}$
0.00000E-99	$+\infty$	$-\infty$
1.00000E-01	1.03658E+02	-5.80502E+01
1.50000E-01	5.45891E+01	-3.31864E+01
2.00000E-01	3.41105E+01	-2.27008E+01
2.50000E-01	2.33570E+01	-1.71208E+01
3.00000E-01	1.69148E+01	-1.37218E+01
3.50000E-01	1.27098E+01	-1.14569E+01
4.00000E-01	9.79431E-00	-9.84647E-00
4.50000E-01	7.67877E-00	-8.64227E-00
5.00000E-01	6.08487E-00	-7.70411E-00
5.50000E-01	4.84195E-00	-6.94695E-00
6.00000E-01	3.83965E-00	-6.31614E-00
6.50000E-01	3.00414E-00	-5.77459E-00
7.00000E-01	2.28458E-00	-5.29566E-00
7.50000E-01	1.64435E-00	-4.85870E-00
8.00000E-01	1.05502E-00	-4.44579E-00
8.50000E-01	4.90874E-01	-4.03826E-00
9.00000E-01	-7.86947E-02	-3.61027E-00
9.50000E-01	-7.12436E-01	-3.10637E-00
9.52000E-01	-7.41007E-01	-3.08278E-00
9.54000E-01	-7.69992E-01	-3.05876E-00
9.56000E-01	-7.99421E-01	-3.03429E-00
9.58000E-01	-8.29331E-01	-3.00932E-00
9.60000E-01	-8.59760E-01	-2.98382E-00
9.62000E-01	-8.90753E-01	-2.95773E-00
9.64000E-01	-9.22361E-01	-2.93102E-00
9.66000E-01	-9.54642E-01	-2.90362E-00
9.68000E-01	-9.87661E-01	-2.87547E-00
9.70000E-01	-1.02149E-00	-2.84649E-00
9.72000E-01	-1.05623E-00	-2.81659E-00
9.74000E-01	-1.09199E-00	-2.78566E-00
9.76000E-01	-1.12888E-00	-2.75358E-00
9.78000E-01	-1.16707E-00	-2.72019E-00
9.80000E-01	-1.20675E-00	-2.68530E-00
9.82000E-01	-1.24816E-00	-2.64867E-00
9.84000E-01	-1.29160E-00	-2.60999E-00
9.86000E-01	-1.33749E-00	-2.56884E-00
9.88000E-01	-1.38640E-00	-2.52467E-00
9.90000E-01	-1.43914E-00	-2.47665E-00
9.92000E-01	-1.49696E-00	-2.42353E-00
9.94000E-01	-1.56198E-00	-2.36320E-00
9.96000E-01	-1.63833E-00	-2.29154E-00
9.98000E-01	-1.73667E-00	-2.19787E-00
9.99000E-01	-1.80550E-00	-2.13137E-00
1.00000E-00	-1.96960E-00	-1.96960E-00

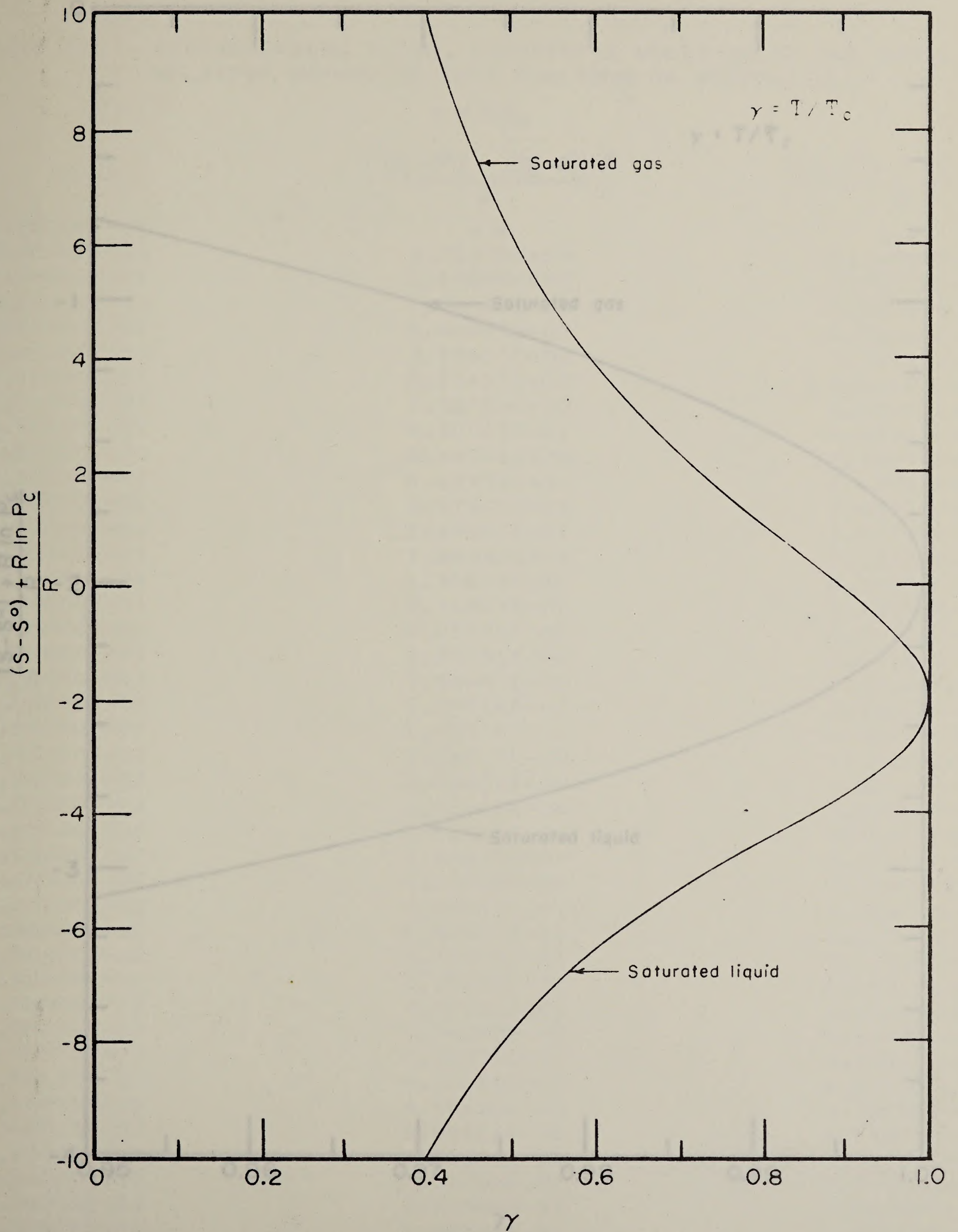


FIGURE 39.- Redlich - Kwong Fluid, Saturated Relative Entropies as a Function of Temperature.

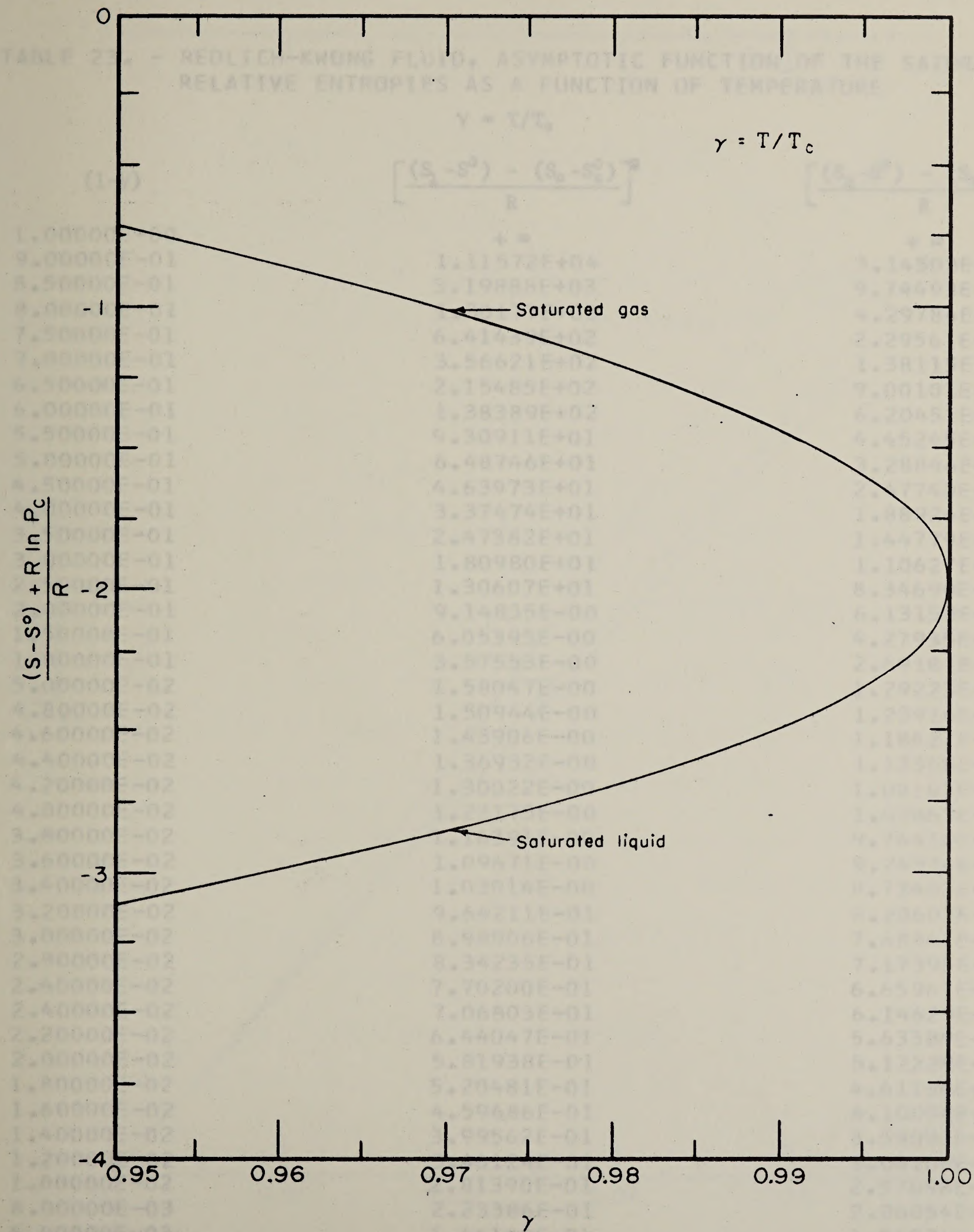


FIGURE 40.—Redlich-Kwong Fluid, Saturated Relative Entropies as a Function of Temperature Near the Critical Point.

TABLE 23. - REDLICH-KWONG FLUID, ASYMPTOTIC FUNCTION OF THE SATURATED RELATIVE ENTROPIES AS A FUNCTION OF TEMPERATURE

$$\gamma = T/T_c$$

(1- γ)	$\left[\frac{(S_1 - S^0) - (S_c - S_c^0)}{R} \right]^2$	$\left[\frac{(S_3 - S^0) - (S_c - S_c^0)}{R} \right]^2$
1.00000E-00	+ ∞	+ ∞
9.00000E-01	1.11572E+04	3.14503E+03
8.50000E-01	3.19888E+03	9.74493E+02
8.00000E-01	1.30177E+03	4.29784E+02
7.50000E-01	6.41439E+02	2.29561E+02
7.00000E-01	3.56621E+02	1.38115E+02
6.50000E-01	2.15485E+02	9.00101E+01
6.00000E-01	1.38389E+02	6.20451E+01
5.50000E-01	9.30911E+01	4.45245E+01
5.00000E-01	6.48746E+01	3.28846E+01
4.50000E-01	4.63973E+01	2.47740E+01
4.00000E-01	3.37474E+01	1.88924E+01
3.50000E-01	2.47382E+01	1.44779E+01
3.00000E-01	1.80980E+01	1.10627E+01
2.50000E-01	1.30607E+01	8.34690E-00
2.00000E-01	9.14835E-00	6.13150E-00
1.50000E-01	6.05395E-00	4.27935E-00
1.00000E-01	3.57553E-00	2.69181E-00
5.00000E-02	1.58047E-00	1.29223E-00
4.80000E-02	1.50944E-00	1.23916E-00
4.60000E-02	1.43906E-00	1.18627E-00
4.40000E-02	1.36932E-00	1.13356E-00
4.20000E-02	1.30022E-00	1.08101E-00
4.00000E-02	1.23175E-00	1.02863E-00
3.80000E-02	1.16391E-00	9.76410E-01
3.60000E-02	1.09671E-00	9.24334E-01
3.40000E-02	1.03014E-00	8.72403E-01
3.20000E-02	9.64211E-01	8.20607E-01
3.00000E-02	8.98906E-01	7.68941E-01
2.80000E-02	8.34235E-01	7.17395E-01
2.60000E-02	7.70200E-01	6.65961E-01
2.40000E-02	7.06803E-01	6.14629E-01
2.20000E-02	6.44047E-01	5.63389E-01
2.00000E-02	5.81938E-01	5.12229E-01
1.80000E-02	5.20481E-01	4.61136E-01
1.60000E-02	4.59686E-01	4.10096E-01
1.40000E-02	3.99562E-01	3.59091E-01
1.20000E-02	3.40124E-01	3.08100E-01
1.00000E-02	2.81390E-01	2.57098E-01
8.00000E-03	2.23386E-01	2.06054E-01
6.00000E-03	1.66149E-01	1.54924E-01
4.00000E-03	1.09737E-01	1.03645E-01
2.00000E-03	5.42539E-02	5.21059E-02
1.00000E-03	2.69279E-02	2.61695E-02
0.00000E-99	0.00000E-99	0.00000E-99

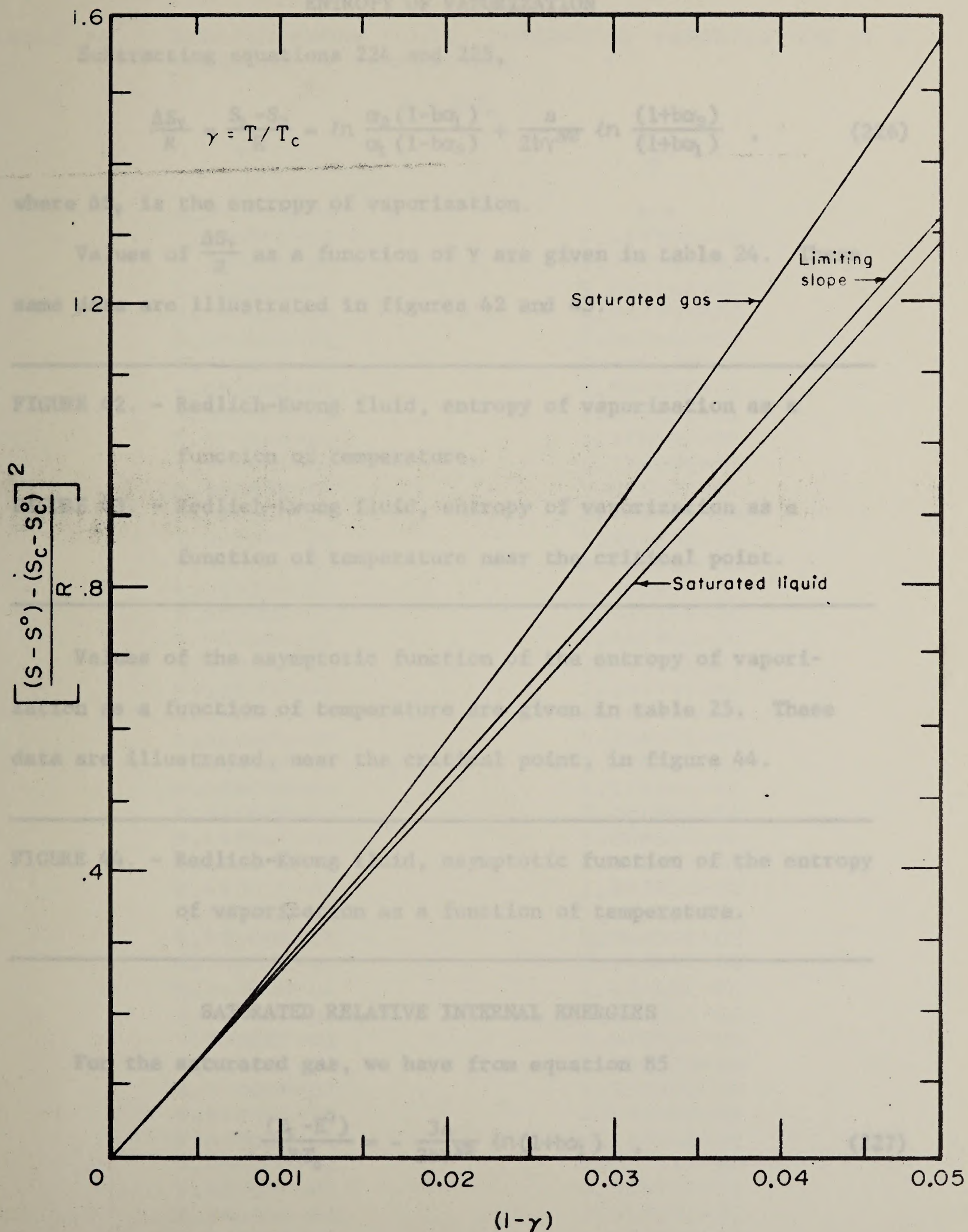


FIGURE 41.—Redlich-Kwong Fluid, Asymptotic Function of the Saturated Relative Entropies as a Function of Temperature.

ENTROPY OF VAPORIZATION

Subtracting equations 224 and 225,

$$\frac{\Delta S_v}{R} = \frac{S_1 - S_3}{R} = \ln \frac{\alpha_3 (1 - b\alpha_1)}{\alpha_1 (1 - b\alpha_3)} + \frac{a}{2b\gamma^{3/2}} \ln \frac{(1 + b\alpha_3)}{(1 + b\alpha_1)}, \quad (226)$$

where ΔS_v is the entropy of vaporization.

Values of $\frac{\Delta S_v}{R}$ as a function of γ are given in table 24. These same data are illustrated in figures 42 and 43.

FIGURE 42. - Redlich-Kwong fluid, entropy of vaporization as a function of temperature.

FIGURE 43. - Redlich-Kwong fluid, entropy of vaporization as a function of temperature near the critical point.

Values of the asymptotic function of the entropy of vaporization as a function of temperature are given in table 25. These data are illustrated, near the critical point, in figure 44.

FIGURE 44. - Redlich-Kwong fluid, asymptotic function of the entropy of vaporization as a function of temperature.

SATURATED RELATIVE INTERNAL ENERGIES

For the saturated gas, we have from equation 85

$$\frac{(E_1 - E^0)}{RT_c} = - \frac{3a}{2b\gamma^{1/2}} \ln(1 + b\alpha_1), \quad (227)$$

TABLE 24. - REDLICH-KWONG FLUID, ENTROPY OF VAPORIZATION AS A FUNCTION OF TEMPERATURE

$$\gamma = T/T_c$$

γ	$\frac{\Delta S_v}{R}$
0.00000E-99	+ ∞
1.00000E-01	1.61708E+02
1.50000E-01	8.77756E+01
2.00000E-01	5.68114E+01
2.50000E-01	4.04779E+01
3.00000E-01	3.06366E+01
3.50000E-01	2.41667E+01
4.00000E-01	1.96407E+01
4.50000E-01	1.63210E+01
5.00000E-01	1.37889E+01
5.50000E-01	1.17889E+01
6.00000E-01	1.01557E+01
6.50000E-01	8.77874E-00
7.00000E-01	7.58024E-00
7.50000E-01	6.50306E-00
8.00000E-01	5.50081E-00
8.50000E-01	4.52914E-00
9.00000E-01	3.53158E-00
9.50000E-01	2.39393E-00
9.52000E-01	2.34177E-00
9.54000E-01	2.28877E-00
9.56000E-01	2.23487E-00
9.58000E-01	2.17999E-00
9.60000E-01	2.12406E-00
9.62000E-01	2.06698E-00
9.64000E-01	2.00866E-00
9.66000E-01	1.94898E-00
9.68000E-01	1.88781E-00
9.70000E-01	1.82499E-00
9.72000E-01	1.76035E-00
9.74000E-01	1.69367E-00
9.76000E-01	1.62469E-00
9.78000E-01	1.55311E-00
9.80000E-01	1.47855E-00
9.82000E-01	1.40051E-00
9.84000E-01	1.31838E-00
9.86000E-01	1.23135E-00
9.88000E-01	1.13826E-00
9.90000E-01	1.03751E-00
9.92000E-01	9.26570E-01
9.94000E-01	8.01219E-01
9.96000E-01	6.53206E-01
9.98000E-01	4.61192E-01
9.99000E-01	3.25867E-01
1.00000E-00	0.00000E-99

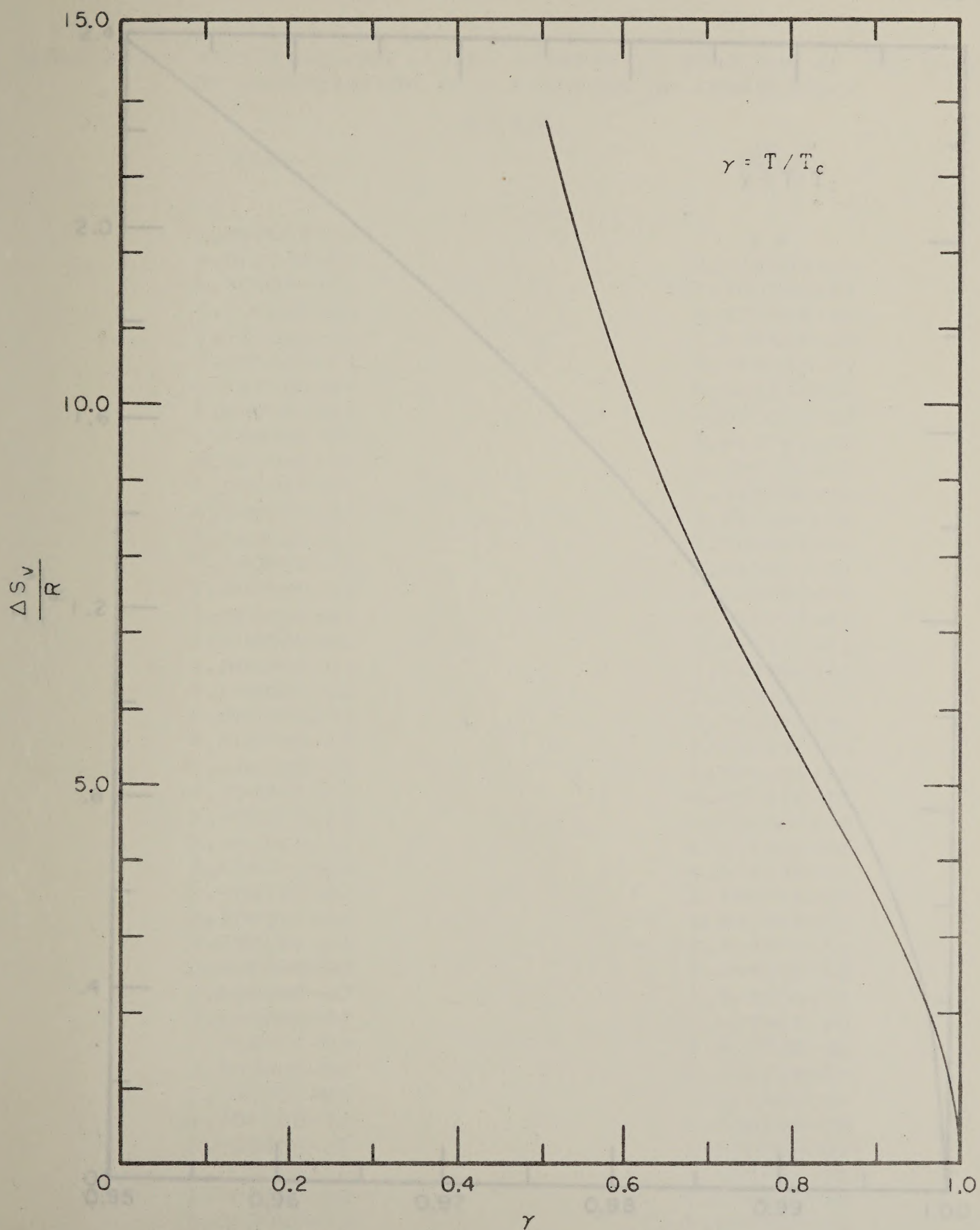


FIGURE 42.—Redlich-Kwong Fluid, Entropy of Vaporization as a Function of Temperature.

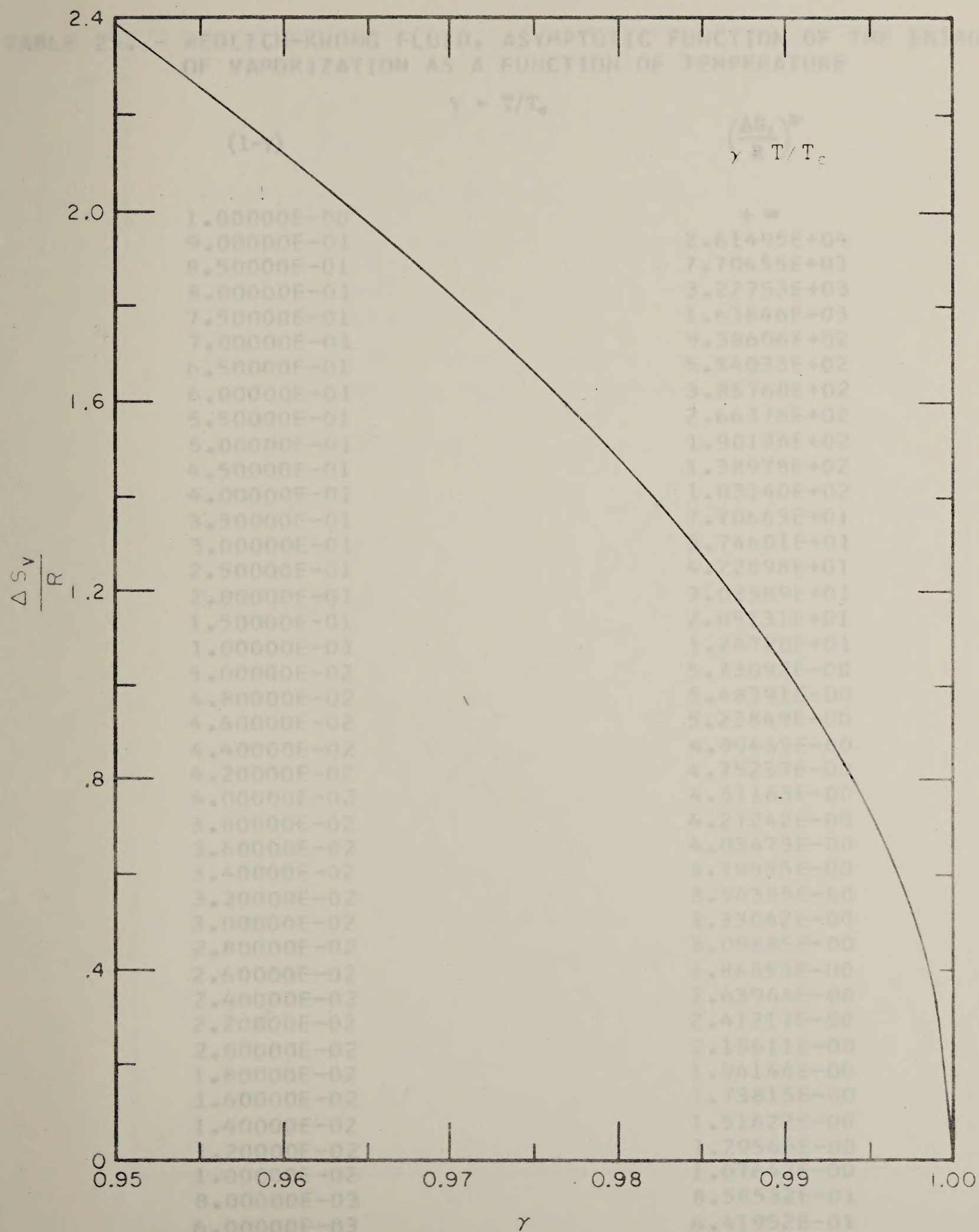


FIGURE 43.- Redlich-Kwong Fluid, Entropy of Vaporization as a Function of Temperature Near the Critical Point.

TABLE 25. - REDLICH-KWONG FLUID, ASYMPTOTIC FUNCTION OF THE ENTROPY OF VAPORIZATION AS A FUNCTION OF TEMPERATURE

$$\gamma = T/T_c$$

$(1-\gamma)$	$\left(\frac{\Delta S_v}{R}\right)^2$
1.00000E-00	+ ∞
9.00000E-01	2.61495E+04
8.50000E-01	7.70455E+03
8.00000E-01	3.22753E+03
7.50000E-01	1.63846E+03
7.00000E-01	9.38606E+02
6.50000E-01	5.84033E+02
6.00000E-01	3.85760E+02
5.50000E-01	2.66376E+02
5.00000E-01	1.90136E+02
4.50000E-01	1.38978E+02
4.00000E-01	1.03140E+02
3.50000E-01	7.70663E+01
3.00000E-01	5.74601E+01
2.50000E-01	4.22898E+01
2.00000E-01	3.02589E+01
1.50000E-01	2.05131E+01
1.00000E-01	1.24720E+01
5.00000E-02	5.73092E-00
4.80000E-02	5.48391E-00
4.60000E-02	5.23849E-00
4.40000E-02	4.99465E-00
4.20000E-02	4.75237E-00
4.00000E-02	4.51163E-00
3.80000E-02	4.27242E-00
3.60000E-02	4.03473E-00
3.40000E-02	3.79855E-00
3.20000E-02	3.56385E-00
3.00000E-02	3.33062E-00
2.80000E-02	3.09885E-00
2.60000E-02	2.86853E-00
2.40000E-02	2.63964E-00
2.20000E-02	2.41217E-00
2.00000E-02	2.18611E-00
1.80000E-02	1.96144E-00
1.60000E-02	1.73815E-00
1.40000E-02	1.51622E-00
1.20000E-02	1.29565E-00
1.00000E-02	1.07642E-00
8.00000E-03	8.58532E-01
6.00000E-03	6.41952E-01
4.00000E-03	4.26678E-01
2.00000E-03	2.12698E-01
1.00000E-03	1.06189E-01
0.00000E-99	0.00000E-99

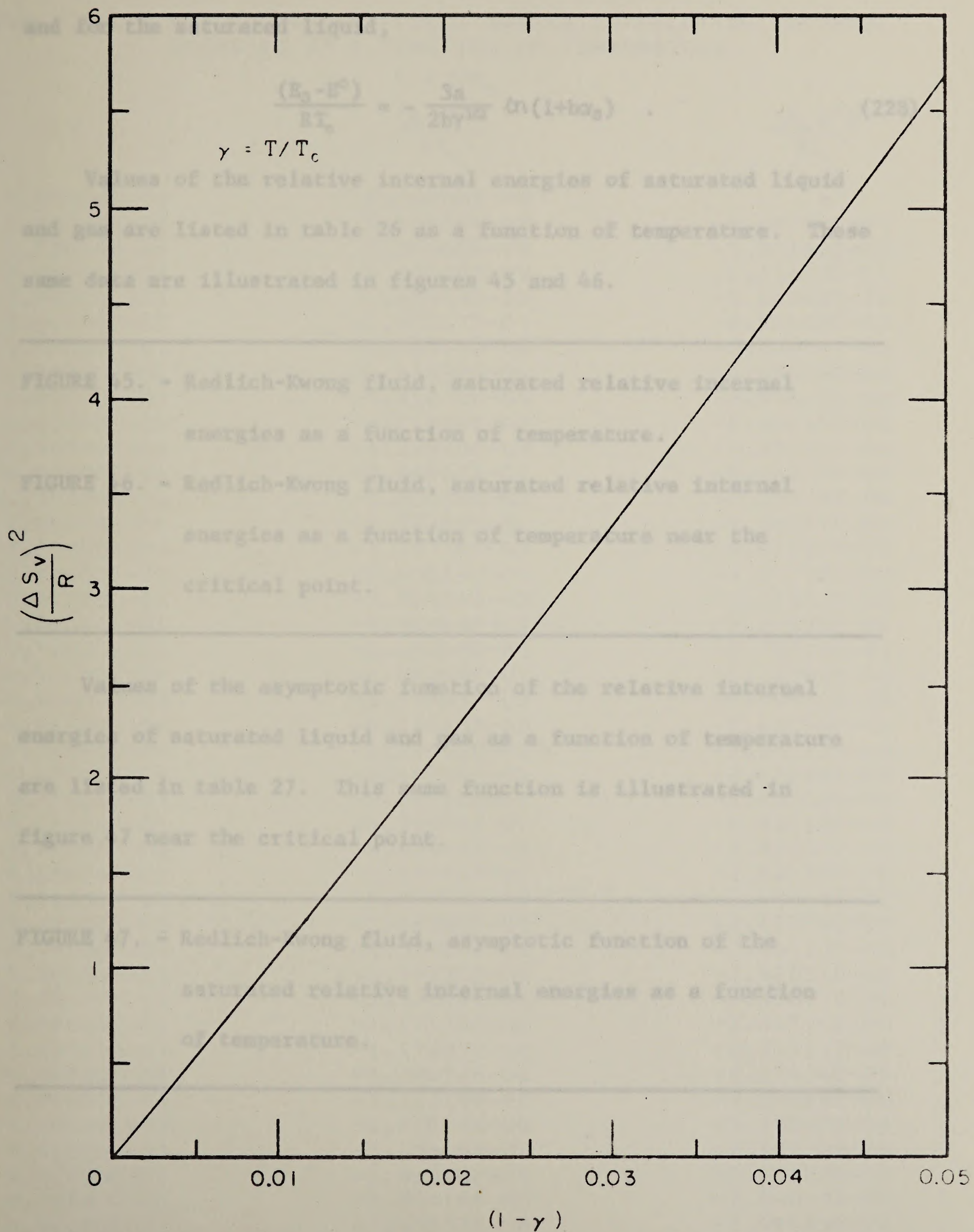


FIGURE 44.-Redlich-Kwong Fluid, Asymptotic Function of the Entropy of Vaporization as a Function of Temperature.

and for the saturated liquid,

$$\frac{(E_3 - E^0)}{RT_c} = - \frac{3a}{2b\gamma^{1/2}} \ln(1 + b\alpha_3) \quad (228)$$

Values of the relative internal energies of saturated liquid and gas are listed in table 26 as a function of temperature. These same data are illustrated in figures 45 and 46.

FIGURE 45. - Redlich-Kwong fluid, saturated relative internal energies as a function of temperature.

FIGURE 46. - Redlich-Kwong fluid, saturated relative internal energies as a function of temperature near the critical point.

Values of the asymptotic function of the relative internal energies of saturated liquid and gas as a function of temperature are listed in table 27. This same function is illustrated in figure 47 near the critical point.

FIGURE 47. - Redlich-Kwong fluid, asymptotic function of the saturated relative internal energies as a function of temperature.

TABLE 26. - REDLICH-KWONG FLUID, SATURATED RELATIVE INTERNAL ENERGIES AS A FUNCTION OF TEMPERATURE

$\gamma = T/T_c$		
γ	$\frac{(E_1 - E^0)}{RT_c}$	$\frac{(E_3 - E^0)}{RT_c}$
0.00000E-99	0.00000E-99	- ∞
1.00000E-01	0.00000E-99	-1.60708E+01
1.50000E-01	0.00000E-99	-1.30163E+01
2.00000E-01	0.00000E-99	-1.11622E+01
2.50000E-01	-3.68344E-10	-9.86948E-00
3.00000E-01	-1.75917E-07	-8.89100E-00
3.50000E-01	-9.35614E-06	-8.10839E-00
4.00000E-01	-1.41332E-04	-7.45655E-00
4.50000E-01	-9.81672E-04	-6.89611E-00
5.00000E-01	-4.11599E-03	-6.40139E-00
5.50000E-01	-1.22910E-02	-5.95452E-00
6.00000E-01	-2.90566E-02	-5.54229E-00
6.50000E-01	-5.83185E-02	-5.15429E-00
7.00000E-01	-1.04205E-01	-4.78161E-00
7.50000E-01	-1.71376E-01	-4.41581E-00
8.00000E-01	-2.65864E-01	-4.04770E-00
8.50000E-01	-3.96934E-01	-3.66531E-00
9.00000E-01	-5.81968E-01	-3.24891E-00
9.50000E-01	-8.65245E-01	-2.75214E-00
9.52000E-01	-8.80168E-01	-2.72902E-00
9.54000E-01	-8.95505E-01	-2.70551E-00
9.56000E-01	-9.11283E-01	-2.68159E-00
9.58000E-01	-9.27532E-01	-2.65722E-00
9.60000E-01	-9.44285E-01	-2.63238E-00
9.62000E-01	-9.61580E-01	-2.60702E-00
9.64000E-01	-9.79458E-01	-2.58110E-00
9.66000E-01	-9.97968E-01	-2.55457E-00
9.68000E-01	-1.01716E-00	-2.52738E-00
9.70000E-01	-1.03711E-00	-2.49946E-00
9.72000E-01	-1.05789E-00	-2.47074E-00
9.74000E-01	-1.07959E-00	-2.44113E-00
9.76000E-01	-1.10230E-00	-2.41051E-00
9.78000E-01	-1.12617E-00	-2.37877E-00
9.80000E-01	-1.15136E-00	-2.34574E-00
9.82000E-01	-1.17805E-00	-2.31122E-00
9.84000E-01	-1.20652E-00	-2.27496E-00
9.86000E-01	-1.23710E-00	-2.23660E-00
9.88000E-01	-1.27027E-00	-2.19569E-00
9.90000E-01	-1.30669E-00	-2.15154E-00
9.92000E-01	-1.34740E-00	-2.10312E-00
9.94000E-01	-1.39416E-00	-2.04869E-00
9.96000E-01	-1.45037E-00	-1.98483E-00
9.98000E-01	-1.52481E-00	-1.90276E-00
9.99000E-01	-1.57825E-00	-1.84551E-00
1.00000E-00	-1.70998E-00	-1.70998E-00

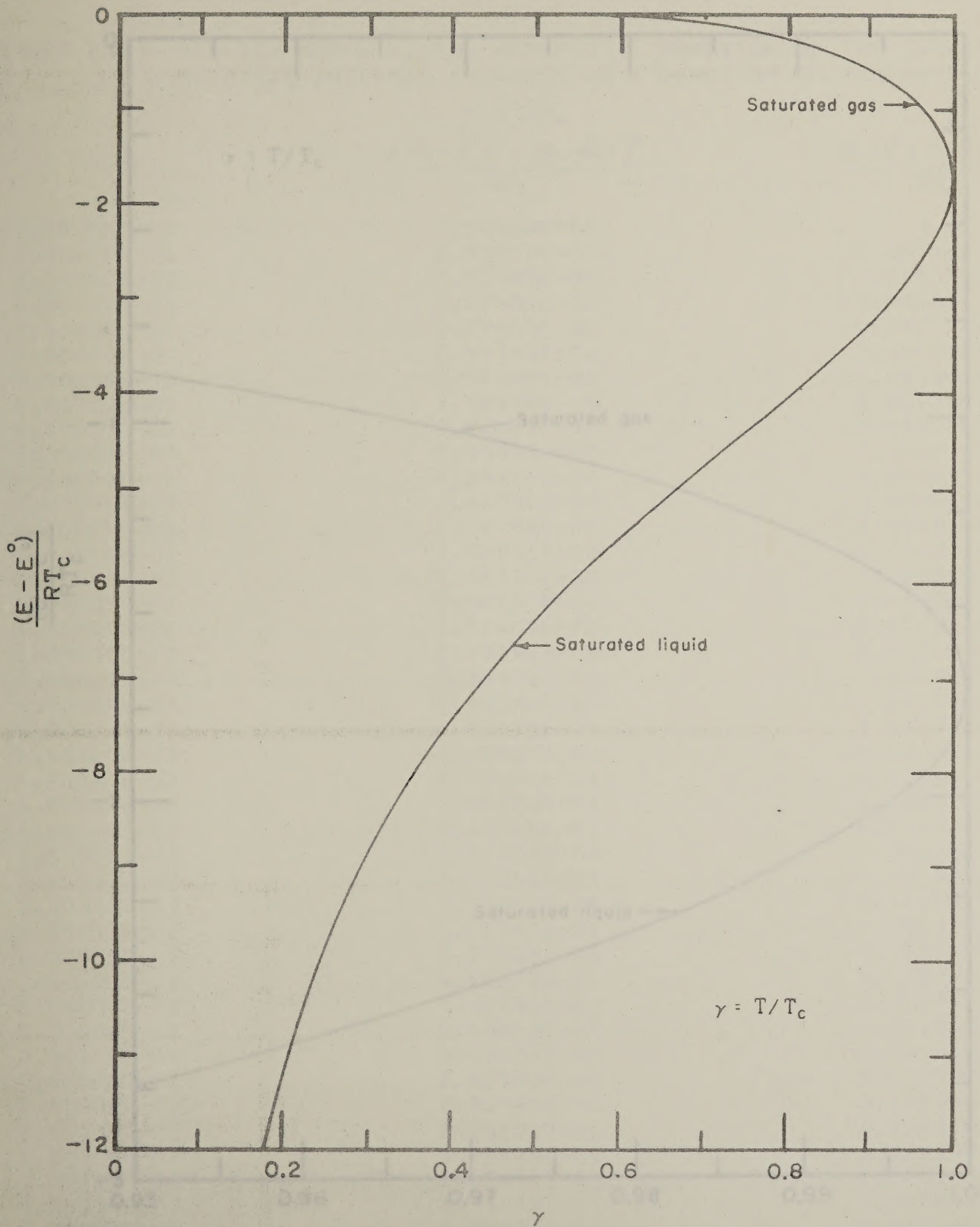


FIGURE 45.- Redlich-Kwong Fluid, Saturated Relative Internal Energies as a Function of Temperature.

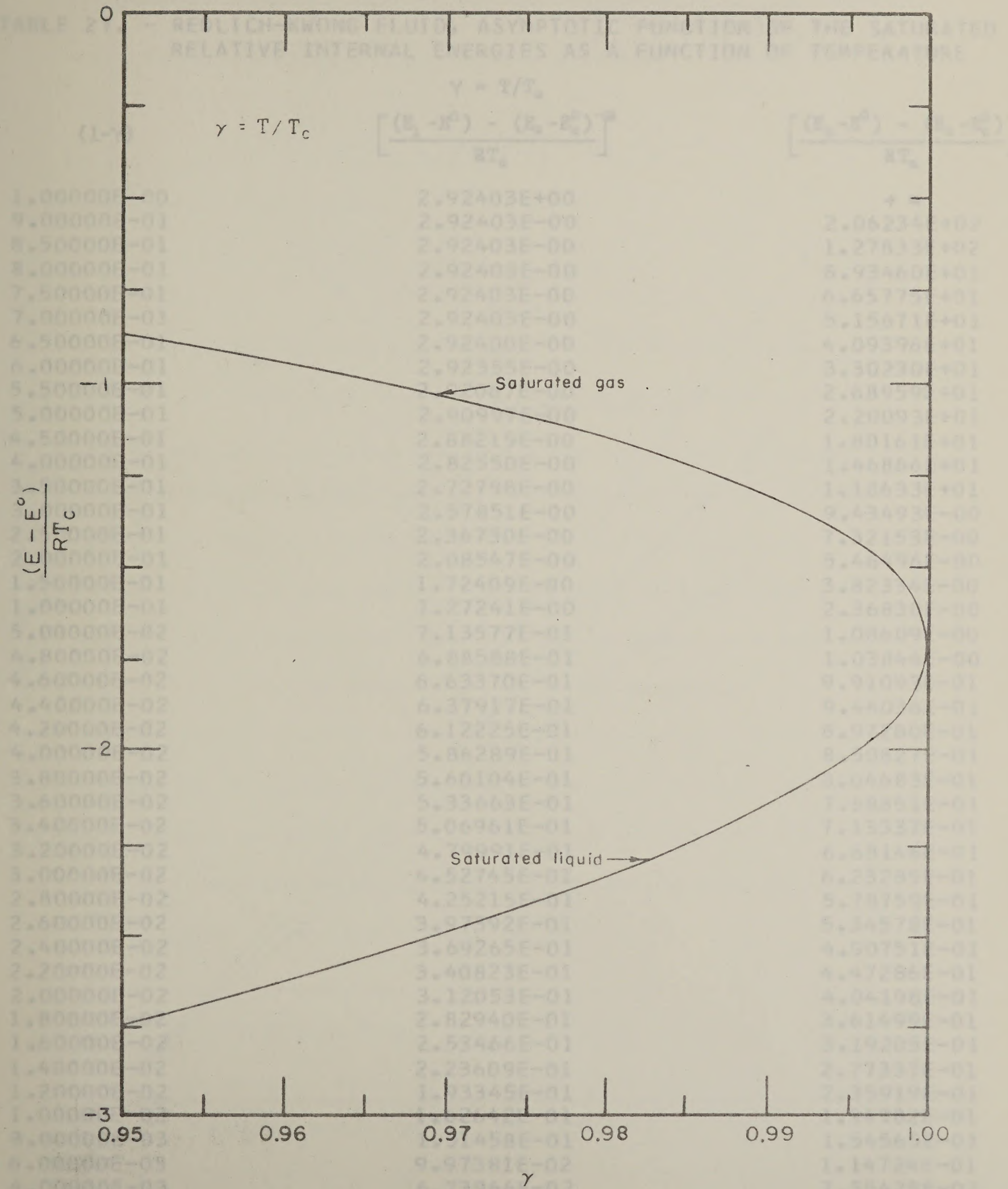


TABLE 27. - REDLICH-KWONG FLUID, ASYMPTOTIC FUNCTION OF THE SATURATED RELATIVE INTERNAL ENERGIES AS A FUNCTION OF TEMPERATURE

$$\gamma = T/T_c$$

$(1-\gamma)$	$\left[\frac{(E_1 - E^0) - (E_c - E_c^0)}{RT_c} \right]^2$	$\left[\frac{(E_3 - E^0) - (E_c - E_c^0)}{RT_c} \right]^2$
1.00000E-00	2.92403E+00	+ ∞
9.00000E-01	2.92403E-00	2.06234E+02
8.50000E-01	2.92403E-00	1.27833E+02
8.00000E-01	2.92403E-00	8.93460E+01
7.50000E-01	2.92403E-00	6.65775E+01
7.00000E-01	2.92403E-00	5.15671E+01
6.50000E-01	2.92400E-00	4.09396E+01
6.00000E-01	2.92355E-00	3.30230E+01
5.50000E-01	2.92067E-00	2.68959E+01
5.00000E-01	2.90997E-00	2.20093E+01
4.50000E-01	2.88215E-00	1.80161E+01
4.00000E-01	2.82550E-00	1.46866E+01
3.50000E-01	2.72798E-00	1.18633E+01
3.00000E-01	2.57851E-00	9.43493E-00
2.50000E-01	2.36730E-00	7.32153E-00
2.00000E-01	2.08547E-00	5.46496E-00
1.50000E-01	1.72409E-00	3.82334E-00
1.00000E-01	1.27241E-00	2.36830E-00
5.00000E-02	7.13577E-01	1.08609E-00
4.80000E-02	6.88588E-01	1.03844E-00
4.60000E-02	6.63370E-01	9.91093E-01
4.40000E-02	6.37917E-01	9.44036E-01
4.20000E-02	6.12225E-01	8.97280E-01
4.00000E-02	5.86289E-01	8.50827E-01
3.80000E-02	5.60104E-01	8.04683E-01
3.60000E-02	5.33663E-01	7.58851E-01
3.40000E-02	5.06961E-01	7.13337E-01
3.20000E-02	4.79991E-01	6.68146E-01
3.00000E-02	4.52745E-01	6.23285E-01
2.80000E-02	4.25215E-01	5.78759E-01
2.60000E-02	3.97392E-01	5.34578E-01
2.40000E-02	3.69265E-01	4.90751E-01
2.20000E-02	3.40823E-01	4.47286E-01
2.00000E-02	3.12053E-01	4.04198E-01
1.80000E-02	2.82940E-01	3.61499E-01
1.60000E-02	2.53466E-01	3.19205E-01
1.40000E-02	2.23609E-01	2.77337E-01
1.20000E-02	1.93345E-01	2.35919E-01
1.00000E-02	1.62642E-01	1.94982E-01
8.00000E-03	1.31458E-01	1.54565E-01
6.00000E-03	9.97381E-02	1.14724E-01
4.00000E-03	6.73966E-02	7.55425E-02
2.00000E-03	3.42880E-02	3.71638E-02
1.00000E-03	1.73527E-02	1.83688E-02
0.00000E-99	0.00000E-99	0.00000E-99

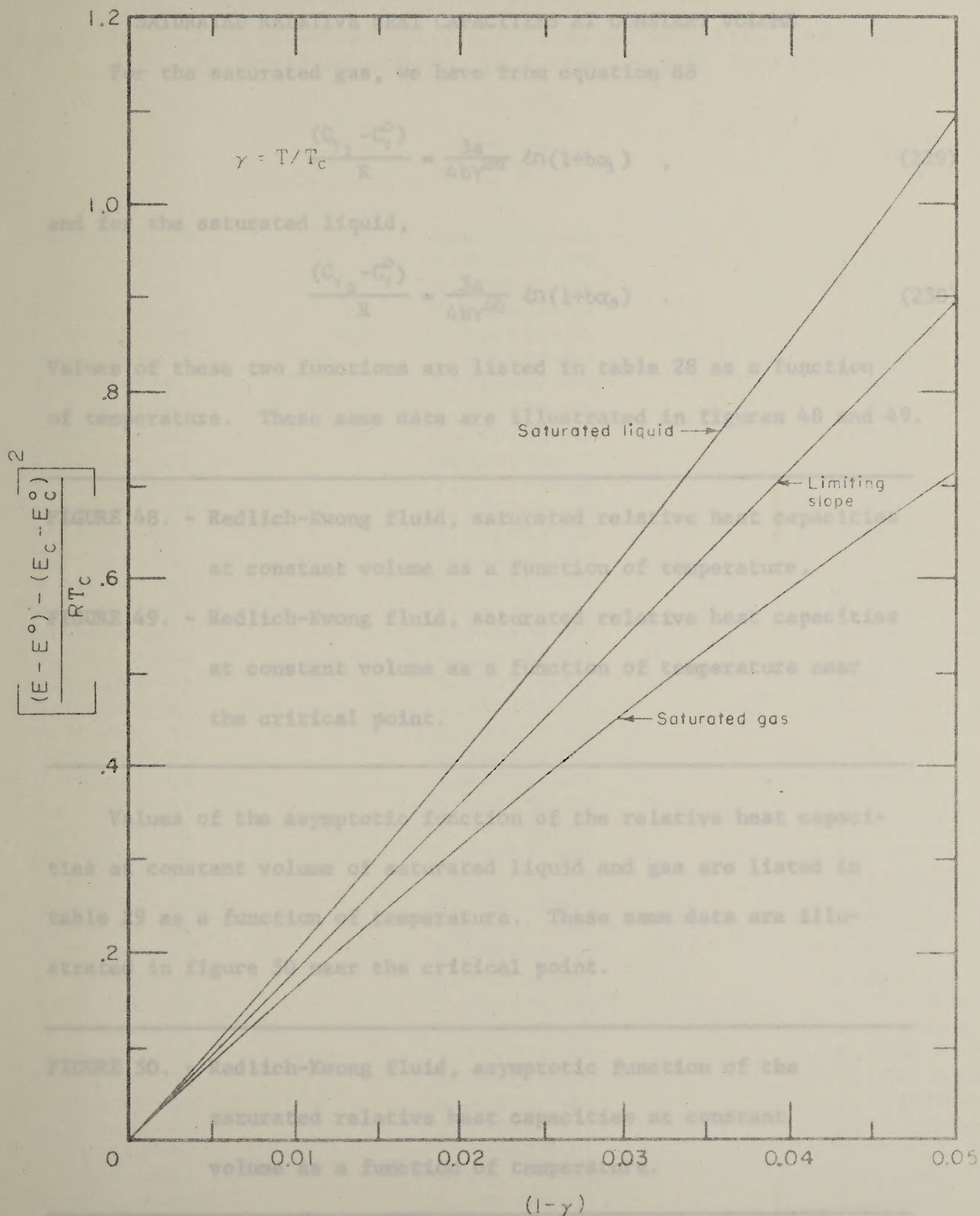


FIGURE 47.- Redlich-Kwong Fluid, Asymptotic Function of the Saturated Relative Internal Energies as a Function of Temperature.

SATURATED RELATIVE HEAT CAPACITIES AT CONSTANT VOLUME

For the saturated gas, we have from equation 88

$$\frac{(C_{v1} - C_v^0)}{R} = \frac{3a}{4b\gamma^{3/2}} \ln(1+b\alpha_1) \quad , \quad (229)$$

and for the saturated liquid,

$$\frac{(C_{v3} - C_v^0)}{R} = \frac{3a}{4b\gamma^{3/2}} \ln(1+b\alpha_3) \quad . \quad (230)$$

Values of these two functions are listed in table 28 as a function of temperature. These same data are illustrated in figures 48 and 49.

FIGURE 48. - Redlich-Kwong fluid, saturated relative heat capacities at constant volume as a function of temperature.

FIGURE 49. - Redlich-Kwong fluid, saturated relative heat capacities at constant volume as a function of temperature near the critical point.

Values of the asymptotic function of the relative heat capacities at constant volume of saturated liquid and gas are listed in table 29 as a function of temperature. These same data are illustrated in figure 50 near the critical point.

FIGURE 50. - Redlich-Kwong fluid, asymptotic function of the saturated relative heat capacities at constant volume as a function of temperature.

TABLE 28. - REDLICH-KWONG FLUID, SATURATED RELATIVE HEAT CAPACITIES AT CONSTANT VOLUME AS A FUNCTION OF TEMPERATURE

γ	$\gamma = T/T_c$ $\frac{C_{V1} - C_V^0}{R}$	$\frac{C_{V2} - C_V^0}{R}$
0.00000E-99	0.00000E-99	$+\infty$
1.00000E-01	0.00000E-99	8.03541E+01
1.50000E-01	0.00000E-99	4.33878E+01
2.00000E-01	0.00000E-99	2.79057E+01
2.50000E-01	7.36689E-10	1.97389E+01
3.00000E-01	2.93195E-07	1.48183E+01
3.50000E-01	1.33659E-05	1.15834E+01
4.00000E-01	1.76665E-04	9.32069E-00
4.50000E-01	1.09074E-03	7.66235E-00
5.00000E-01	4.11599E-03	6.40139E-00
5.50000E-01	1.11737E-02	5.41320E-00
6.00000E-01	2.42138E-02	4.61858E-00
6.50000E-01	4.48604E-02	3.96484E-00
7.00000E-01	7.44326E-02	3.41543E-00
7.50000E-01	1.14251E-01	2.94387E-00
8.00000E-01	1.66165E-01	2.52981E-00
8.50000E-01	2.33490E-01	2.15606E-00
9.00000E-01	3.23316E-01	1.80495E-00
9.50000E-01	4.55392E-01	1.44849E-00
9.52000E-01	4.62273E-01	1.43331E-00
9.54000E-01	4.69342E-01	1.41798E-00
9.56000E-01	4.76612E-01	1.40250E-00
9.58000E-01	4.84098E-01	1.38686E-00
9.60000E-01	4.91815E-01	1.37103E-00
9.62000E-01	4.99781E-01	1.35500E-00
9.64000E-01	5.08017E-01	1.33874E-00
9.66000E-01	5.16546E-01	1.32224E-00
9.68000E-01	5.25396E-01	1.30546E-00
9.70000E-01	5.34596E-01	1.28838E-00
9.72000E-01	5.44184E-01	1.27095E-00
9.74000E-01	5.54204E-01	1.25314E-00
9.76000E-01	5.64707E-01	1.23489E-00
9.78000E-01	5.75756E-01	1.21614E-00
9.80000E-01	5.87430E-01	1.19680E-00
9.82000E-01	5.99826E-01	1.17679E-00
9.84000E-01	6.13072E-01	1.15597E-00
9.86000E-01	6.27336E-01	1.13418E-00
9.88000E-01	6.42849E-01	1.11118E-00
9.90000E-01	6.59945E-01	1.08664E-00
9.92000E-01	6.79137E-01	1.06004E-00
9.94000E-01	7.01291E-01	1.03052E-00
9.96000E-01	7.28098E-01	9.96401E-01
9.98000E-01	7.63933E-01	9.53286E-01
9.99000E-01	7.89915E-01	9.23680E-01
1.00000E-00	8.54990E-01	8.54990E-01

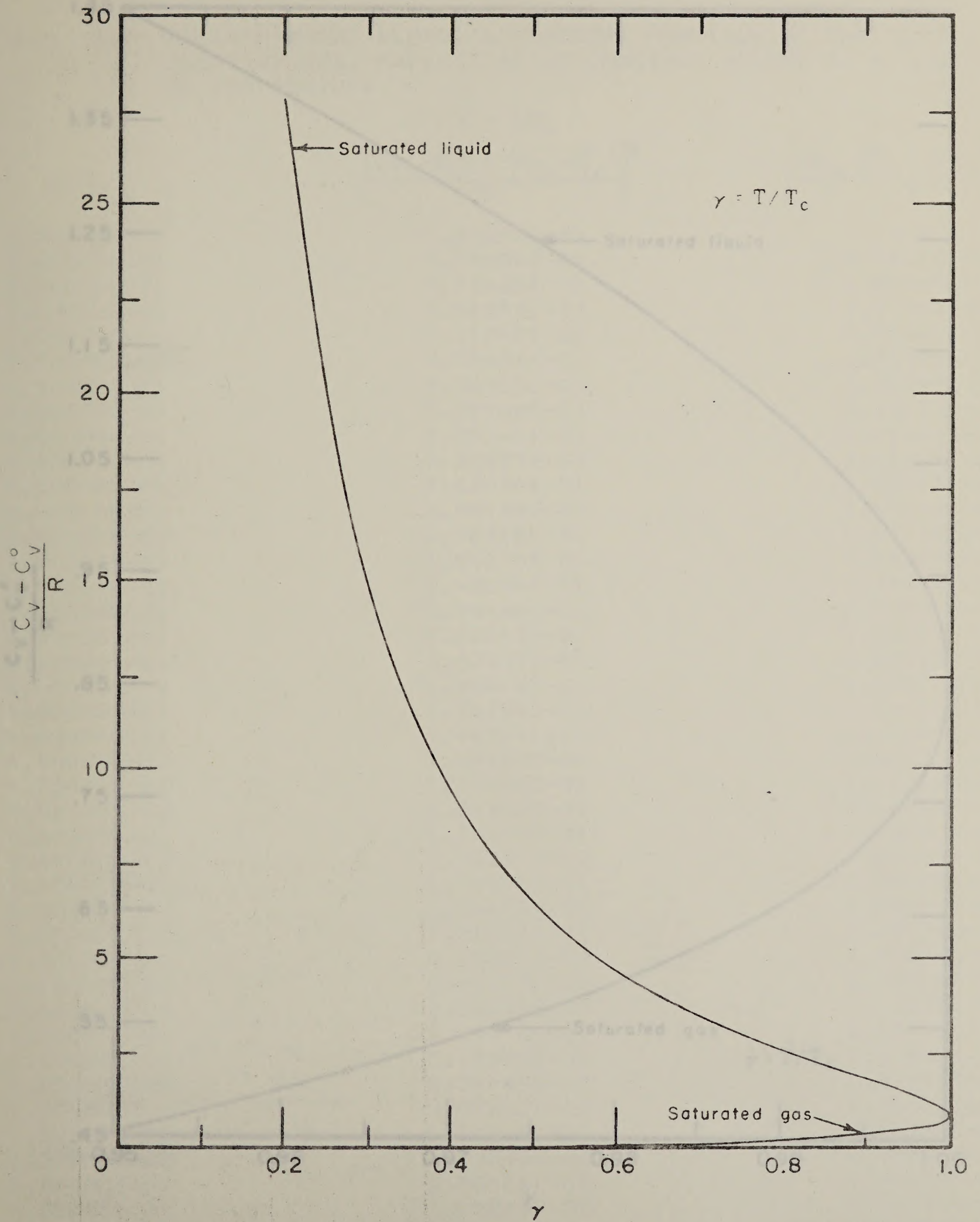


FIGURE 48.- Redlich-Kwong Fluid, Saturated Relative Heat Capacities at Constant Volume as a Function of Temperature.

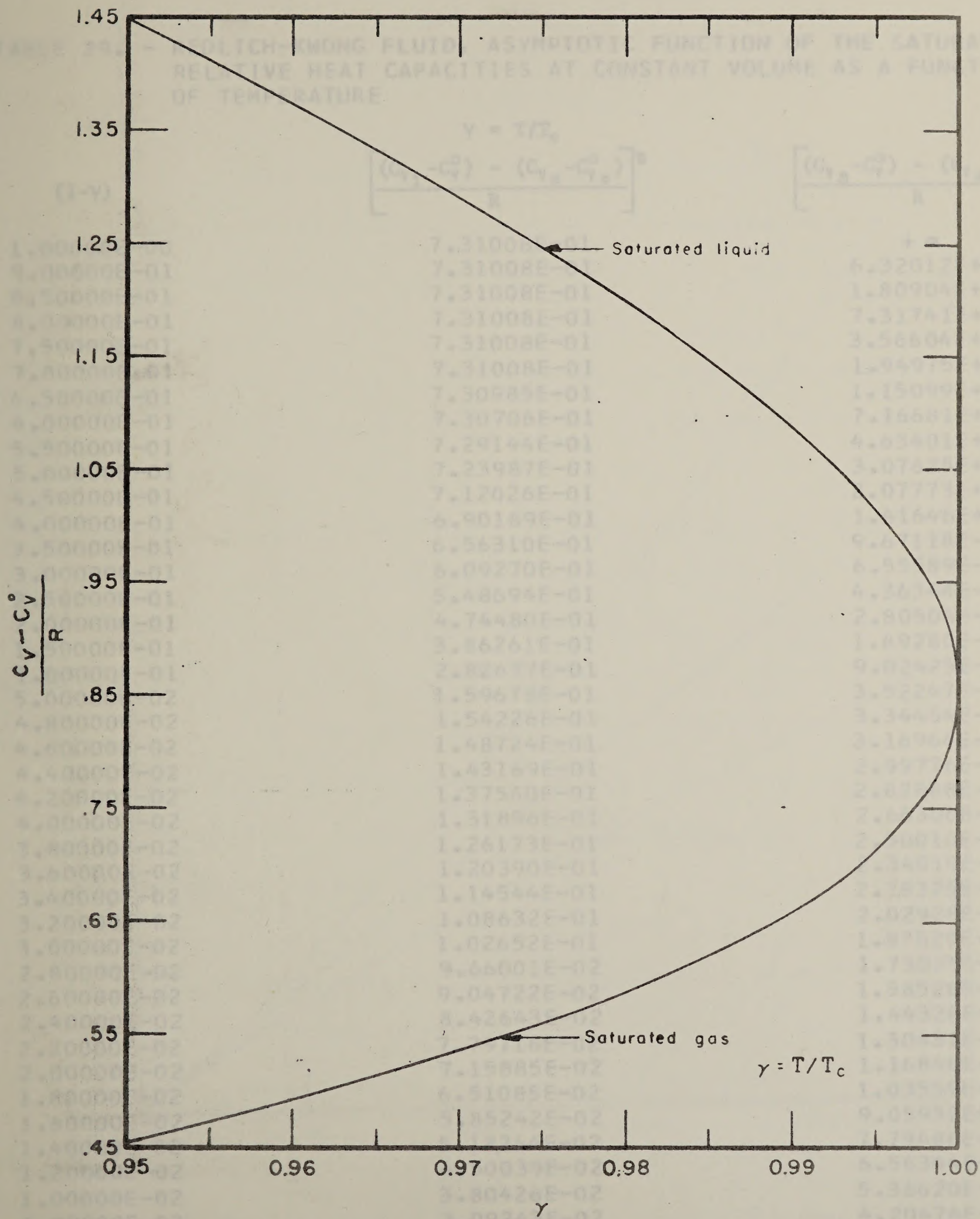


FIGURE 49.—Redlich-Kwong Fluid, Saturated Relative Heat Capacities at Constant Volume as a Function of Temperature Near the Critical Point.

TABLE 29. - REDLICH-KWONG FLUID, ASYMPTOTIC FUNCTION OF THE SATURATED RELATIVE HEAT CAPACITIES AT CONSTANT VOLUME AS A FUNCTION OF TEMPERATURE

(1- γ)	$\gamma = T/T_c$	
	$\left[\frac{(C_{V_1} - C_V^0) - (C_{V_c} - C_{V_c}^0)}{R} \right]^2$	$\left[\frac{(C_{V_3} - C_V^0) - (C_{V_c} - C_{V_c}^0)}{R} \right]^2$
1.00000E-00	7.31008E-01	+ ∞
9.00000E-01	7.31008E-01	6.32012E+03
8.50000E-01	7.31008E-01	1.80904E+03
8.00000E-01	7.31008E-01	7.31741E+02
7.50000E-01	7.31008E-01	3.56604E+02
7.00000E-01	7.31008E-01	1.94975E+02
6.50000E-01	7.30985E-01	1.15099E+02
6.00000E-01	7.30706E-01	7.16681E+01
5.50000E-01	7.29144E-01	4.63401E+01
5.00000E-01	7.23987E-01	3.07625E+01
4.50000E-01	7.12026E-01	2.07773E+01
4.00000E-01	6.90189E-01	1.41646E+01
3.50000E-01	6.56310E-01	9.67118E-00
3.00000E-01	6.09270E-01	6.55589E-00
2.50000E-01	5.48694E-01	4.36344E-00
2.00000E-01	4.74480E-01	2.80504E-00
1.50000E-01	3.86261E-01	1.69280E-00
1.00000E-01	2.82677E-01	9.02423E-01
5.00000E-02	1.59678E-01	3.52247E-01
4.80000E-02	1.54226E-01	3.34454E-01
4.60000E-02	1.48724E-01	3.16964E-01
4.40000E-02	1.43169E-01	2.99776E-01
4.20000E-02	1.37560E-01	2.82888E-01
4.00000E-02	1.31896E-01	2.66300E-01
3.80000E-02	1.26173E-01	2.50010E-01
3.60000E-02	1.20390E-01	2.34019E-01
3.40000E-02	1.14544E-01	2.18325E-01
3.20000E-02	1.08632E-01	2.02928E-01
3.00000E-02	1.02652E-01	1.87829E-01
2.80000E-02	9.66001E-02	1.73029E-01
2.60000E-02	9.04722E-02	1.58528E-01
2.40000E-02	8.42643E-02	1.44328E-01
2.20000E-02	7.79716E-02	1.30431E-01
2.00000E-02	7.15885E-02	1.16840E-01
1.80000E-02	6.51085E-02	1.03559E-01
1.60000E-02	5.85242E-02	9.05932E-02
1.40000E-02	5.18264E-02	7.79486E-02
1.20000E-02	4.50039E-02	6.56344E-02
1.00000E-02	3.80426E-02	5.36620E-02
8.00000E-03	3.09243E-02	4.20474E-02
6.00000E-03	2.36233E-02	3.08137E-02
4.00000E-03	1.61015E-02	1.99969E-02
2.00000E-03	8.29142E-03	9.66214E-03
1.00000E-03	4.23476E-03	4.71824E-03
0.00000E-99	0.00000E-99	0.00000E-99

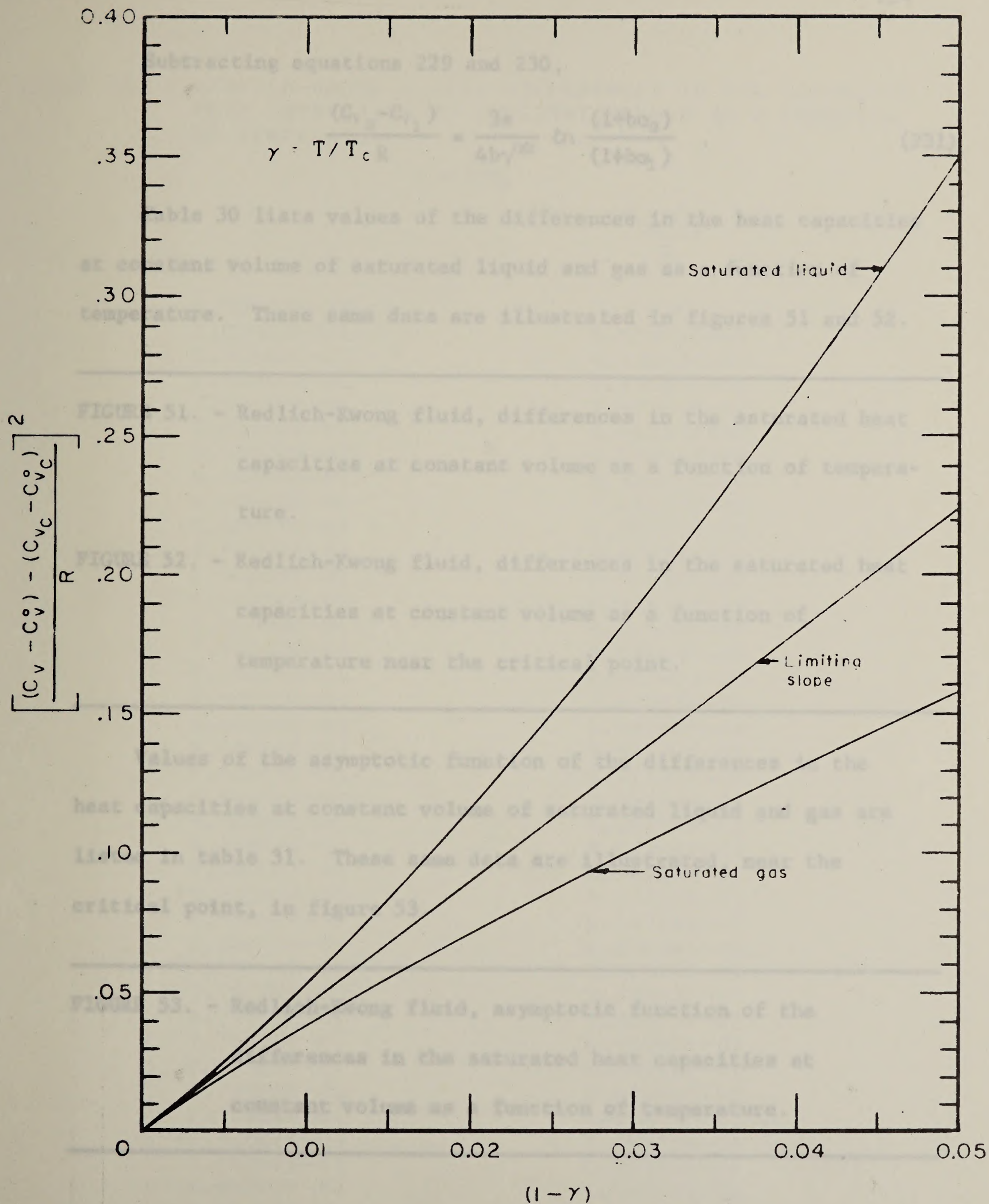


FIGURE 50. - Redlich-Kwong Fluid, Asymptotic Function of the Saturated Relative Heat Capacities at Constant Volume as a Function of Temperature.

Subtracting equations 229 and 230,

$$\frac{(C_{v3} - C_{v1})}{R} = \frac{3a}{4b\gamma^{3/2}} \ln \frac{(1+b\alpha_3)}{(1+b\alpha_1)} \quad (231)$$

Table 30 lists values of the differences in the heat capacities at constant volume of saturated liquid and gas as a function of temperature. These same data are illustrated in figures 51 and 52.

FIGURE 51. - Redlich-Kwong fluid, differences in the saturated heat capacities at constant volume as a function of temperature.

FIGURE 52. - Redlich-Kwong fluid, differences in the saturated heat capacities at constant volume as a function of temperature near the critical point.

Values of the asymptotic function of the differences in the heat capacities at constant volume of saturated liquid and gas are listed in table 31. These same data are illustrated, near the critical point, in figure 53.

FIGURE 53. - Redlich-Kwong fluid, asymptotic function of the differences in the saturated heat capacities at constant volume as a function of temperature.

TABLE 30. - REDLICH-KWONG FLUID, DIFFERENCES IN THE SATURATED HEAT CAPACITIES AT CONSTANT VOLUME AS A FUNCTION OF TEMPERATURE

$$\gamma = T/T_c$$

γ	$\frac{C_{v3} - C_{v1}}{R}$
0.00000E-99	$+\infty$
1.00000E-01	8.03541E+01
1.50000E-01	4.33878E+01
2.00000E-01	2.79057E+01
2.50000E-01	1.97389E+01
3.00000E-01	1.48183E+01
3.50000E-01	1.15834E+01
4.00000E-01	9.32051E-00
4.50000E-01	7.66125E-00
5.00000E-01	6.39727E-00
5.50000E-01	5.40202E-00
6.00000E-01	4.59436E-00
6.50000E-01	3.91998E-00
7.00000E-01	3.34100E-00
7.50000E-01	2.82962E-00
8.00000E-01	2.36365E-00
8.50000E-01	1.92257E-00
9.00000E-01	1.48163E-00
9.50000E-01	9.93102E-01
9.52000E-01	9.71037E-01
9.54000E-01	9.48643E-01
9.56000E-01	9.25895E-01
9.58000E-01	9.02764E-01
9.60000E-01	8.79218E-01
9.62000E-01	8.55219E-01
9.64000E-01	8.30728E-01
9.66000E-01	8.05696E-01
9.68000E-01	7.80070E-01
9.70000E-01	7.53787E-01
9.72000E-01	7.26773E-01
9.74000E-01	6.98942E-01
9.76000E-01	6.70188E-01
9.78000E-01	6.40386E-01
9.80000E-01	6.09379E-01
9.82000E-01	5.76970E-01
9.84000E-01	5.42904E-01
9.86000E-01	5.06847E-01
9.88000E-01	4.68333E-01
9.90000E-01	4.26695E-01
9.92000E-01	3.80907E-01
9.94000E-01	3.29237E-01
9.96000E-01	2.68302E-01
9.98000E-01	1.89353E-01
9.99000E-01	1.33764E-01
1.00000E-00	0.00000E-99

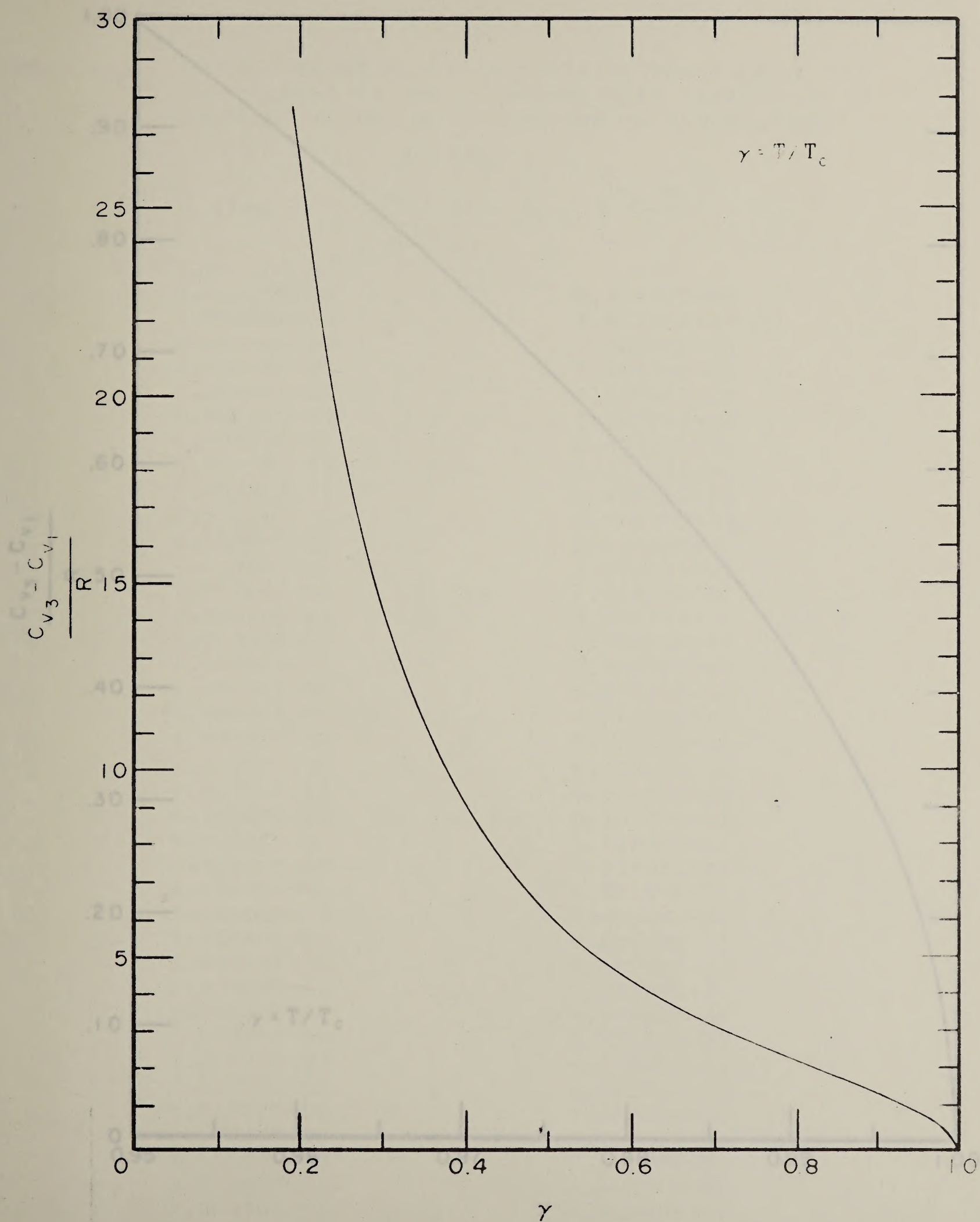


FIGURE 51. —Redlich-Kwong Fluid, Differences in the Saturated Heat Capacities at Constant Volume as a Function of Temperature.

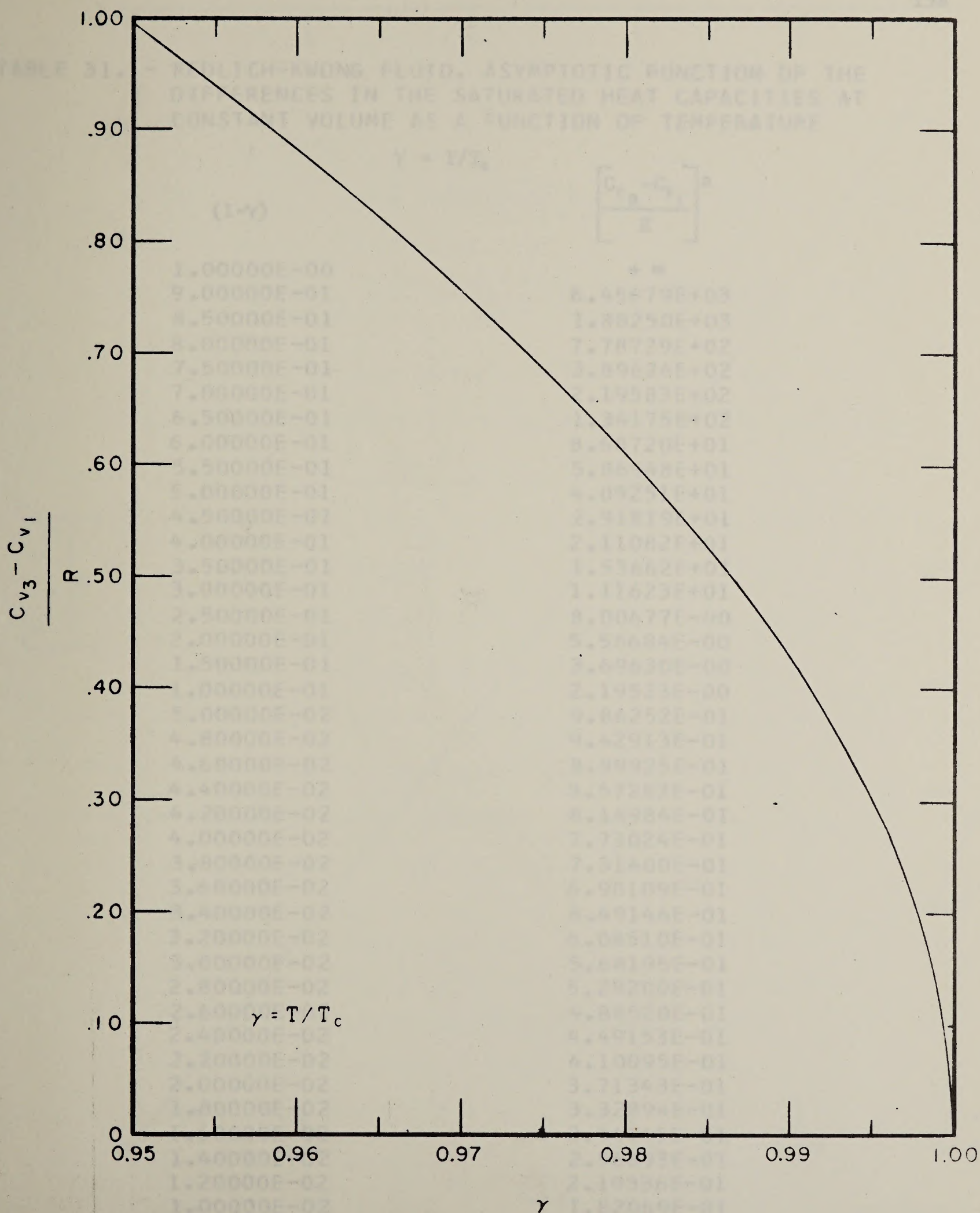


FIGURE 52.—Redlich-Kwong Fluid, Differences in the Saturated Heat Capacities at Constant Volume as a Function of Temperature Near the Critical Point.

TABLE 31. - REDLICH-KWONG FLUID, ASYMPTOTIC FUNCTION OF THE DIFFERENCES IN THE SATURATED HEAT CAPACITIES AT CONSTANT VOLUME AS A FUNCTION OF TEMPERATURE

$$\gamma = T/T_c$$

$$(1-\gamma)$$

$$\left[\frac{C_{v_3} - C_{v_1}}{R} \right]^2$$

$$+ \infty$$

1.00000E-00	+ ∞
9.00000E-01	6.45679E+03
8.50000E-01	1.88250E+03
8.00000E-01	7.78729E+02
7.50000E-01	3.89626E+02
7.00000E-01	2.19583E+02
6.50000E-01	1.34175E+02
6.00000E-01	8.68720E+01
5.50000E-01	5.86948E+01
5.00000E-01	4.09251E+01
4.50000E-01	2.91819E+01
4.00000E-01	2.11082E+01
3.50000E-01	1.53662E+01
3.00000E-01	1.11623E+01
2.50000E-01	8.00677E-00
2.00000E-01	5.58684E-00
1.50000E-01	3.69630E-00
1.00000E-01	2.19523E-00
5.00000E-02	9.86252E-01
4.80000E-02	9.42913E-01
4.60000E-02	8.99925E-01
4.40000E-02	8.57283E-01
4.20000E-02	8.14984E-01
4.00000E-02	7.73024E-01
3.80000E-02	7.31400E-01
3.60000E-02	6.90109E-01
3.40000E-02	6.49146E-01
3.20000E-02	6.08510E-01
3.00000E-02	5.68195E-01
2.80000E-02	5.28200E-01
2.60000E-02	4.88520E-01
2.40000E-02	4.49153E-01
2.20000E-02	4.10095E-01
2.00000E-02	3.71343E-01
1.80000E-02	3.32894E-01
1.60000E-02	2.94745E-01
1.40000E-02	2.56893E-01
1.20000E-02	2.19336E-01
1.00000E-02	1.82069E-01
8.00000E-03	1.45090E-01
6.00000E-03	1.08397E-01
4.00000E-03	7.19862E-02
2.00000E-03	3.58547E-02
1.00000E-03	1.78929E-02
0.00000E-99	0.00000E-99

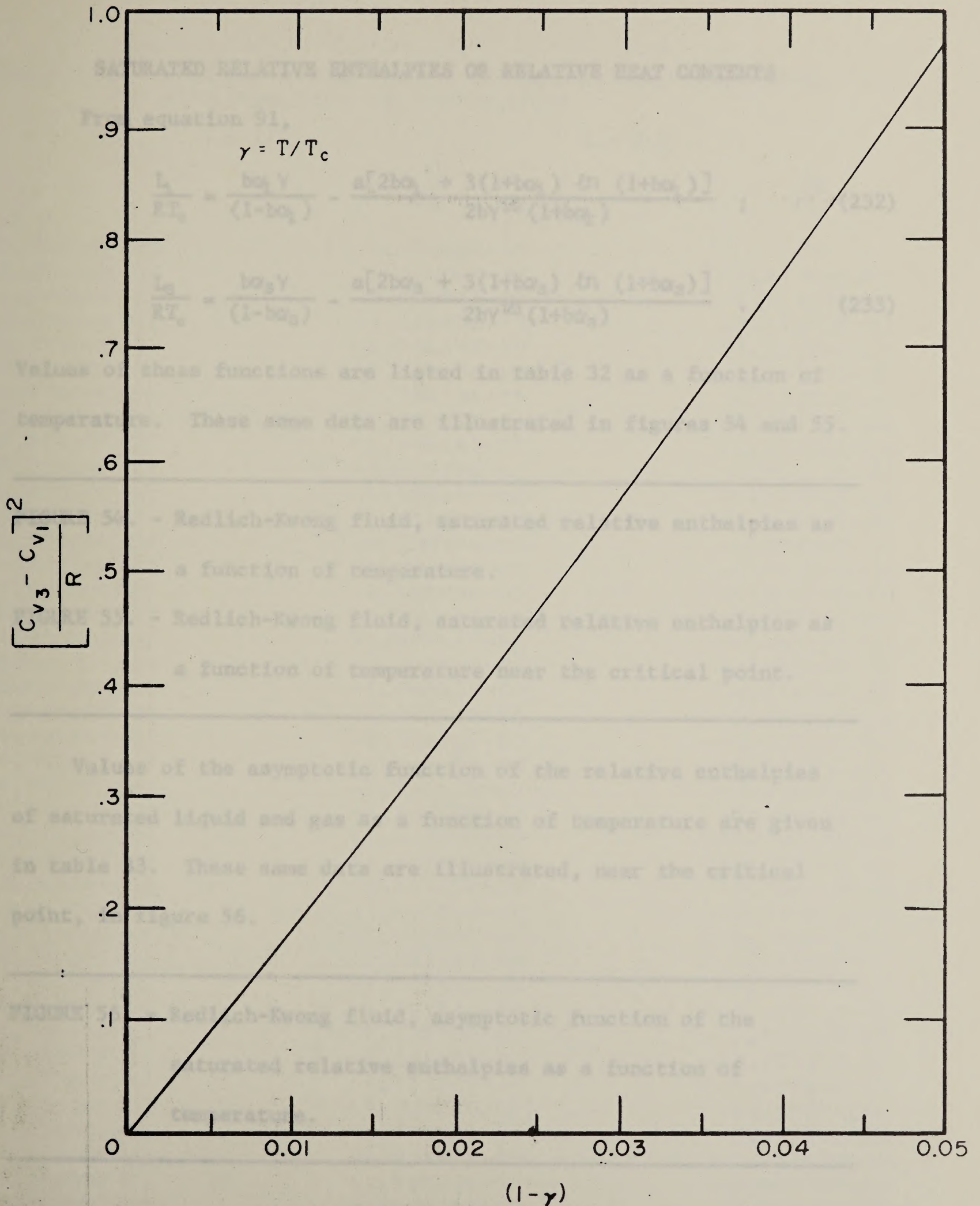


FIGURE 53.—Redlich-Kwong Fluid, Asymptotic Function of the Differences in the Saturated Heat Capacities at Constant Volume as a Function of Temperature.

SATURATED RELATIVE ENTHALPIES OR RELATIVE HEAT CONTENTS

From equation 91,

$$\frac{L_1}{RT_c} = \frac{b\alpha_1 \gamma}{(1-b\alpha_1)} - \frac{a[2b\alpha_1 + 3(1+b\alpha_1) \ln(1+b\alpha_1)]}{2b\gamma^{1/2}(1+b\alpha_1)} ; \quad (232)$$

$$\frac{L_3}{RT_c} = \frac{b\alpha_3 \gamma}{(1-b\alpha_3)} - \frac{a[2b\alpha_3 + 3(1+b\alpha_3) \ln(1+b\alpha_3)]}{2b\gamma^{1/2}(1+b\alpha_3)} . \quad (233)$$

Values of these functions are listed in table 32 as a function of temperature. These same data are illustrated in figures 54 and 55.

FIGURE 54. - Redlich-Kwong fluid, saturated relative enthalpies as a function of temperature.

FIGURE 55. - Redlich-Kwong fluid, saturated relative enthalpies as a function of temperature near the critical point.

Values of the asymptotic function of the relative enthalpies of saturated liquid and gas as a function of temperature are given in table 33. These same data are illustrated, near the critical point, in figure 56.

FIGURE 56. - Redlich-Kwong fluid, asymptotic function of the saturated relative enthalpies as a function of temperature.

TABLE 32. - REDLICH-KWONG FLUID, SATURATED RELATIVE ENTHALPIES
AS A FUNCTION OF TEMPERATURE

$$\gamma = T/T_c$$

$$L = H - H^0$$

γ	$\frac{L_1}{RT_c}$	$\frac{L_3}{RT_c}$
0.00000E-99	0.00000E-99	- ∞
1.00000E-01	0.00000E-99	-1.61708E+01
1.50000E-01	0.00000E-99	-1.31663E+01
2.00000E-01	-7.20000E-15	-1.13622E+01
2.50000E-01	-6.07689E-10	-1.01194E+01
3.00000E-01	-2.89289E-07	-9.19100E-00
3.50000E-01	-1.53318E-05	-8.45839E-00
4.00000E-01	-2.30721E-04	-7.85654E-00
4.50000E-01	-1.59604E-03	-7.34606E-00
5.00000E-01	-6.66271E-03	-6.90116E-00
5.50000E-01	-1.98014E-02	-6.50370E-00
6.00000E-01	-4.65652E-02	-6.14004E-00
6.50000E-01	-9.29052E-02	-5.79909E-00
7.00000E-01	-1.64874E-01	-5.47104E-00
7.50000E-01	-2.68983E-01	-5.14628E-00
8.00000E-01	-4.13286E-01	-4.81393E-00
8.50000E-01	-6.09734E-01	-4.45950E-00
9.00000E-01	-8.80270E-01	-4.05869E-00
9.50000E-01	-1.28002E-00	-3.55426E-00
9.52000E-01	-1.30061E-00	-3.52998E-00
9.54000E-01	-1.32173E-00	-3.50522E-00
9.56000E-01	-1.34340E-00	-3.47994E-00
9.58000E-01	-1.36567E-00	-3.45410E-00
9.60000E-01	-1.38857E-00	-3.42767E-00
9.62000E-01	-1.41215E-00	-3.40059E-00
9.64000E-01	-1.43647E-00	-3.37282E-00
9.66000E-01	-1.46157E-00	-3.34430E-00
9.68000E-01	-1.48754E-00	-3.31495E-00
9.70000E-01	-1.51444E-00	-3.28469E-00
9.72000E-01	-1.54238E-00	-3.25345E-00
9.74000E-01	-1.57146E-00	-3.22110E-00
9.76000E-01	-1.60181E-00	-3.18751E-00
9.78000E-01	-1.63358E-00	-3.15253E-00
9.80000E-01	-1.66699E-00	-3.11597E-00
9.82000E-01	-1.70226E-00	-3.07757E-00
9.84000E-01	-1.73972E-00	-3.03701E-00
9.86000E-01	-1.77978E-00	-2.99390E-00
9.88000E-01	-1.82302E-00	-2.94763E-00
9.90000E-01	-1.87027E-00	-2.89740E-00
9.92000E-01	-1.92278E-00	-2.84194E-00
9.94000E-01	-1.98270E-00	-2.77911E-00
9.96000E-01	-2.05417E-00	-2.70476E-00
9.98000E-01	-2.14791E-00	-2.60818E-00
9.99000E-01	-2.21457E-00	-2.54011E-00
1.00000E-00	-2.37664E-00	-2.37664E-00

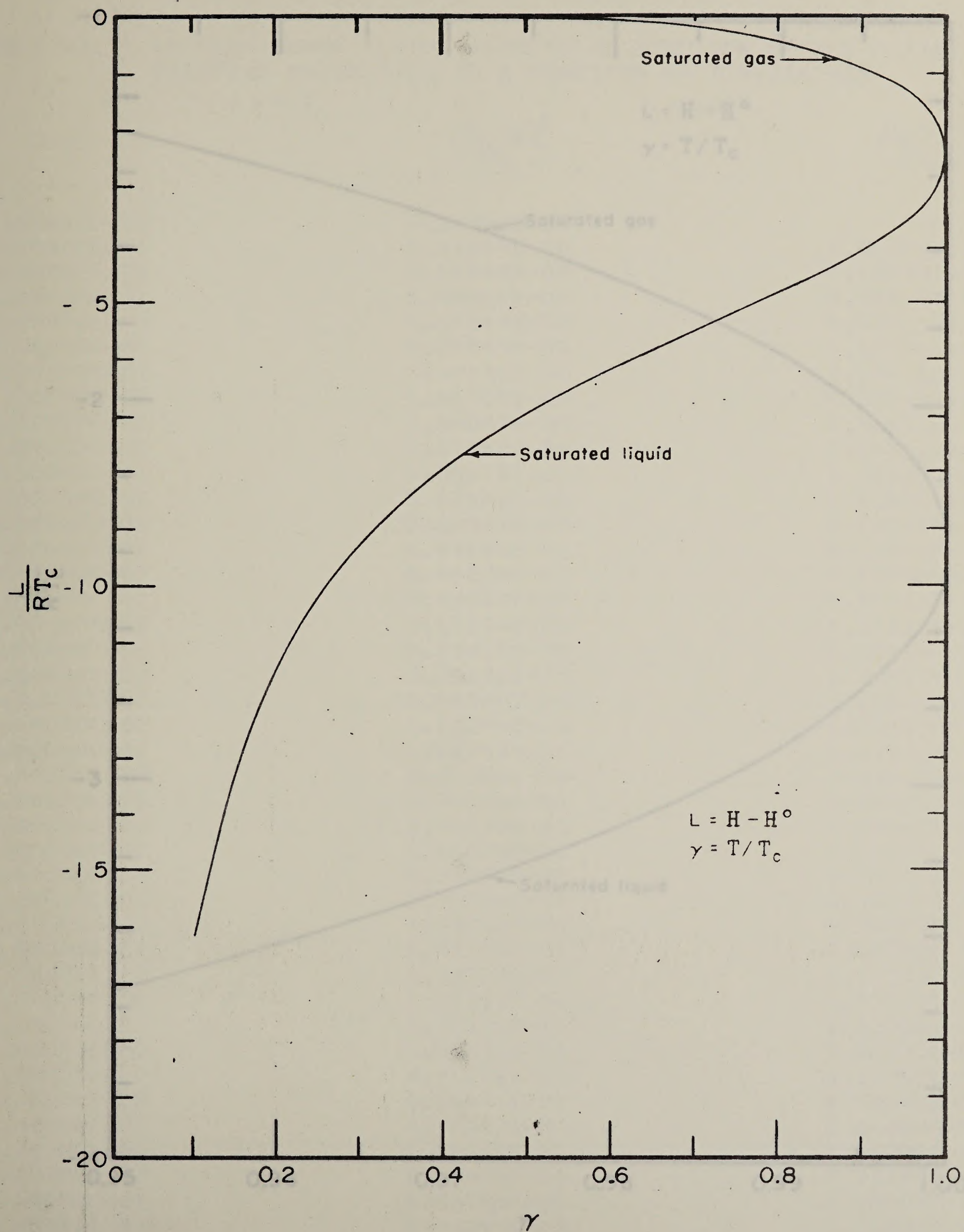


FIGURE 54.— Redlich-Kwong Fluid, Saturated Relative Enthalpies as a Function of Temperature.

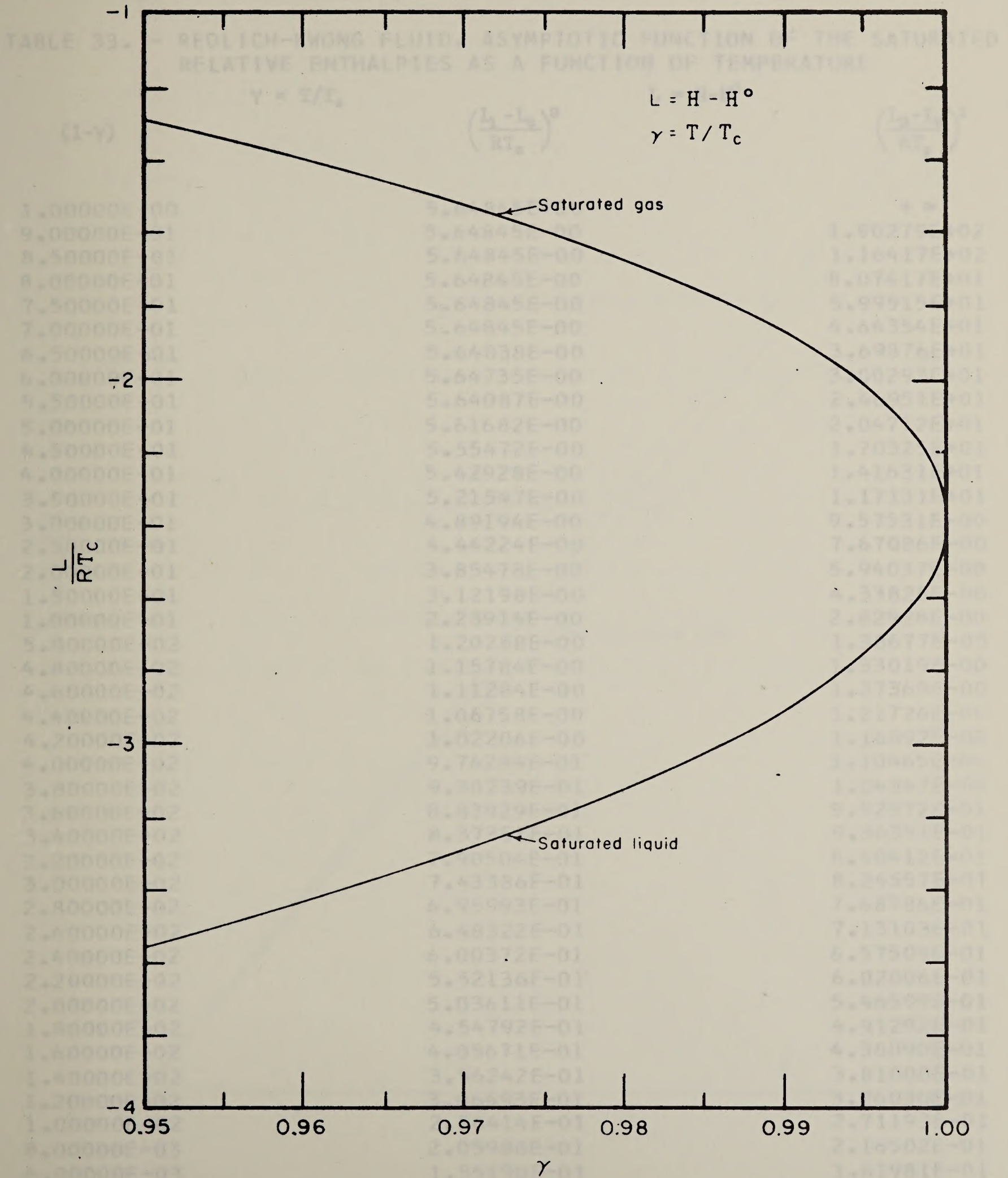


FIGURE 55. - Redlich-Kwong Fluid, Saturated Relative Enthalpies as a Function of Temperature Near the Critical Point.

TABLE 33. - REDLICH-KWONG FLUID, ASYMPTOTIC FUNCTION OF THE SATURATED RELATIVE ENTHALPIES AS A FUNCTION OF TEMPERATURE

$\gamma = T/T_c$	$L = H - H^0$	
$(1-\gamma)$	$\left(\frac{L_1 - L_c}{RT_c}\right)^2$	$\left(\frac{L_2 - L_c}{RT_c}\right)^2$
1.00000E-00	5.64845E+00	+ ∞
9.00000E-01	5.64845E-00	1.90279E+02
8.50000E-01	5.64845E-00	1.16417E+02
8.00000E-01	5.64845E-00	8.07417E+01
7.50000E-01	5.64845E-00	5.99515E+01
7.00000E-01	5.64845E-00	4.64354E+01
6.50000E-01	5.64838E-00	3.69876E+01
6.00000E-01	5.64735E-00	3.00293E+01
5.50000E-01	5.64087E-00	2.46951E+01
5.00000E-01	5.61682E-00	2.04712E+01
4.50000E-01	5.55472E-00	1.70325E+01
4.00000E-01	5.42928E-00	1.41631E+01
3.50000E-01	5.21547E-00	1.17131E+01
3.00000E-01	4.89194E-00	9.57531E-00
2.50000E-01	4.44224E-00	7.67086E-00
2.00000E-01	3.85478E-00	5.94037E-00
1.50000E-01	3.12198E-00	4.33828E-00
1.00000E-01	2.23914E-00	2.82928E-00
5.00000E-02	1.20258E-00	1.38677E-00
4.80000E-02	1.15784E-00	1.33019E-00
4.60000E-02	1.11284E-00	1.27369E-00
4.40000E-02	1.06758E-00	1.21726E-00
4.20000E-02	1.02206E-00	1.16092E-00
4.00000E-02	9.76284E-01	1.10465E-00
3.80000E-02	9.30239E-01	1.04847E-00
3.60000E-02	8.83929E-01	9.92372E-01
3.40000E-02	8.37351E-01	9.36351E-01
3.20000E-02	7.90504E-01	8.80412E-01
3.00000E-02	7.43386E-01	8.24557E-01
2.80000E-02	6.95993E-01	7.68786E-01
2.60000E-02	6.48322E-01	7.13103E-01
2.40000E-02	6.00372E-01	6.57509E-01
2.20000E-02	5.52136E-01	6.02006E-01
2.00000E-02	5.03611E-01	5.46599E-01
1.80000E-02	4.54792E-01	4.91292E-01
1.60000E-02	4.05671E-01	4.36090E-01
1.40000E-02	3.56242E-01	3.81000E-01
1.20000E-02	3.06493E-01	3.26030E-01
1.00000E-02	2.56414E-01	2.71193E-01
8.00000E-03	2.05988E-01	2.16502E-01
6.00000E-03	1.55190E-01	1.61981E-01
4.00000E-03	1.03988E-01	1.07663E-01
2.00000E-03	5.23180E-02	5.36100E-02
1.00000E-03	2.62670E-02	2.67225E-02
0.00000E-99	0.00000E-99	0.00000E-99

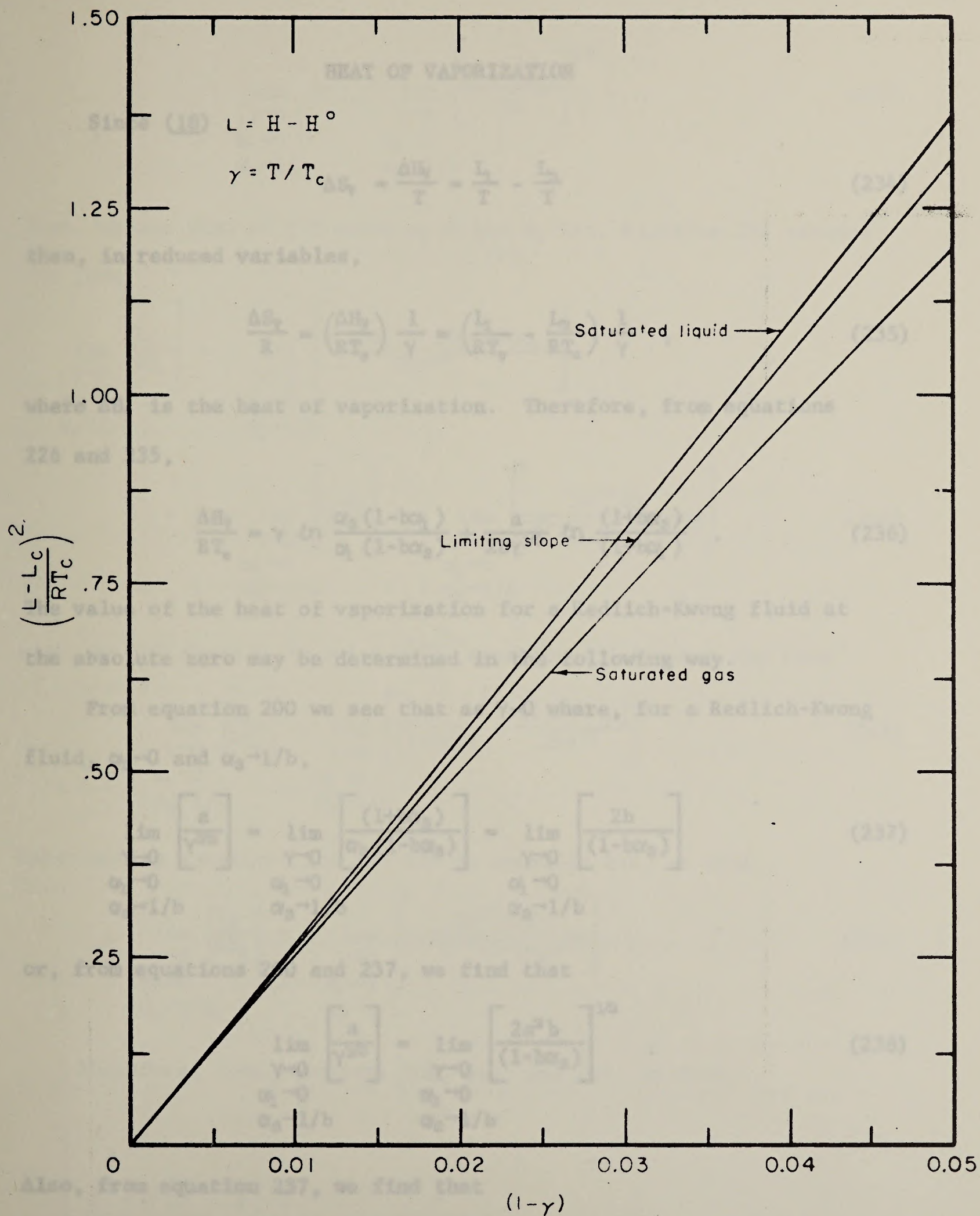


FIGURE 56. - Redlich - Kwong Fluid, Asymptotic Function of the Saturated Relative Enthalpies as a Function of Temperature.

HEAT OF VAPORIZATION

Since (18)

$$\Delta S_v = \frac{\Delta H_v}{T} = \frac{L_1}{T} - \frac{L_3}{T} \quad (234)$$

then, in reduced variables,

$$\frac{\Delta S_v}{R} = \left(\frac{\Delta H_v}{RT_c} \right) \frac{1}{\gamma} = \left(\frac{L_1}{RT_c} - \frac{L_3}{RT_c} \right) \frac{1}{\gamma}, \quad (235)$$

where ΔH_v is the heat of vaporization. Therefore, from equations 226 and 235,

$$\frac{\Delta H_v}{RT_c} = \gamma \ln \frac{\alpha_3(1-b\alpha_1)}{\alpha_1(1-b\alpha_3)} + \frac{a}{2b\gamma^{1/2}} \ln \frac{(1+b\alpha_3)}{(1+b\alpha_1)}. \quad (236)$$

The value of the heat of vaporization for a Redlich-Kwong fluid at the absolute zero may be determined in the following way.

From equation 200 we see that as $\gamma \rightarrow 0$ where, for a Redlich-Kwong fluid, $\alpha_1 \rightarrow 0$ and $\alpha_3 \rightarrow 1/b$,

$$\lim_{\substack{\gamma \rightarrow 0 \\ \alpha_1 \rightarrow 0 \\ \alpha_3 \rightarrow 1/b}} \left[\frac{a}{\gamma^{3/2}} \right] = \lim_{\substack{\gamma \rightarrow 0 \\ \alpha_1 \rightarrow 0 \\ \alpha_3 \rightarrow 1/b}} \left[\frac{(1+b\alpha_3)}{\alpha_3(1-b\alpha_3)} \right] = \lim_{\substack{\gamma \rightarrow 0 \\ \alpha_1 \rightarrow 0 \\ \alpha_3 \rightarrow 1/b}} \left[\frac{2b}{(1-b\alpha_3)} \right] \quad (237)$$

or, from equations 200 and 237, we find that

$$\lim_{\substack{\gamma \rightarrow 0 \\ \alpha_1 \rightarrow 0 \\ \alpha_3 \rightarrow 1/b}} \left[\frac{a}{\gamma^{1/2}} \right] = \lim_{\substack{\gamma \rightarrow 0 \\ \alpha_1 \rightarrow 0 \\ \alpha_3 \rightarrow 1/b}} \left[\frac{2a^2 b}{(1-b\alpha_3)} \right]^{1/3}. \quad (238)$$

Also, from equation 237, we find that

$$\lim_{\substack{\gamma \rightarrow 0 \\ \alpha_1 \rightarrow 0 \\ \alpha_3 \rightarrow 1/b}} [\gamma] = \lim_{\substack{\gamma \rightarrow 0 \\ \alpha_1 \rightarrow 0 \\ \alpha_3 \rightarrow 1/b}} \left[\frac{a(1-b\alpha_3)}{2b} \right]^{2/3} \quad (239)$$

Thus, we see that as $\gamma \rightarrow 0$ where $\alpha_1 \rightarrow 0$ and $\alpha_3 \rightarrow 1/b$, equation 232 assumes the form

$$\begin{aligned} \lim_{\substack{\gamma \rightarrow 0 \\ \alpha_1 \rightarrow 0 \\ \alpha_3 \rightarrow 1/b}} \left[\frac{L_1}{RT_c} \right] &= - \lim_{\substack{\gamma \rightarrow 0 \\ \alpha_1 \rightarrow 0 \\ \alpha_3 \rightarrow 1/b}} \left[\frac{a[2b\alpha_1 + 3\ln(1+b\alpha_1)]}{2b\gamma^{1/2}} \right], \\ &= - \lim_{\substack{\gamma \rightarrow 0 \\ \alpha_1 \rightarrow 0 \\ \alpha_3 \rightarrow 1/b}} \left[\frac{5a\alpha_1}{2\gamma^{1/2}} \right] = - \lim_{\substack{\gamma \rightarrow 0 \\ \alpha_1 \rightarrow 0 \\ \alpha_3 \rightarrow 1/b}} \left[\frac{5a^{2/3}b\alpha_1}{2^{2/3}b^{2/3}(1-b\alpha_3)^{1/3}} \right]. \end{aligned} \quad (240)$$

Also, as $\gamma \rightarrow 0$ where $\alpha_1 \rightarrow 0$ and $\alpha_3 \rightarrow 1/b$, equation 233 assumes the form

$$\lim_{\substack{\gamma \rightarrow 0 \\ \alpha_1 \rightarrow 0 \\ \alpha_3 \rightarrow 1/b}} \left[\frac{L_3}{RT_c} \right] = \lim_{\substack{\gamma \rightarrow 0 \\ \alpha_1 \rightarrow 0 \\ \alpha_3 \rightarrow 1/b}} \left[\frac{\gamma}{(1-b\alpha_3)} - \frac{a[1+3\ln 2]}{2b\gamma^{1/2}} \right]. \quad (241)$$

Substituting equations 238 and 239 in equation 241, we find

$$\lim_{\substack{\gamma \rightarrow 0 \\ \alpha_1 \rightarrow 0 \\ \alpha_3 \rightarrow 1/b}} \left[\frac{L_3}{RT_c} \right] = - \lim_{\substack{\gamma \rightarrow 0 \\ \alpha_1 \rightarrow 0 \\ \alpha_3 \rightarrow 1/b}} \left[\frac{3a^{2/3}\ln 2}{2^{2/3}b^{2/3}(1-b\alpha_3)^{1/3}} \right]. \quad (242)$$

Therefore, from equations 235, 240, and 242, we find

$$\begin{aligned}
\lim_{\substack{\gamma \rightarrow 0 \\ \alpha_1 \rightarrow 0 \\ \alpha_3 \rightarrow 1/b}} \left[\frac{\Delta H_v}{RT_c} \right] &= \lim_{\substack{\gamma \rightarrow 0 \\ \alpha_1 \rightarrow 0 \\ \alpha_3 \rightarrow 1/b}} \left[\frac{L_1 - L_3}{RT_c} \right], \\
&= \lim_{\substack{\gamma \rightarrow 0 \\ \alpha_1 \rightarrow 0 \\ \alpha_3 \rightarrow 1/b}} \left[\frac{a^{2/3} (3 \ln 2 - 5b\alpha_1)}{2^{2/3} b^{2/3} (1 - b\alpha_3)^{1/3}} \right] = +\infty.
\end{aligned} \tag{243}$$

Thus, the heat of vaporization for a Redlich-Kwong fluid at absolute zero is infinite.

Landau and Lifshitz (17) say that for temperatures appreciably below the critical temperature, $\Delta H_v/RT_c$ is approximately equal to 10; Barieau (5) shows that for a van der Waals fluid $\left. \frac{\Delta H_v}{RT_c} \right|_{\gamma=0} = 3.375$.

Table 34 lists values of the heat of vaporization as a function of temperature. These same data are illustrated in figures 57 and 58.

FIGURE 57. - Redlich-Kwong fluid, heat of vaporization as a function of temperature.

FIGURE 58. - Redlich-Kwong fluid, heat of vaporization as a function of temperature near the critical point.

Values of the asymptotic function of the heat of vaporization as a function of $(1-\gamma)$ are listed in table 35. These same data are

TABLE 34. - REDLICH-KWONG FLUID, HEAT OF VAPORIZATION AS A FUNCTION OF TEMPERATURE

$$\gamma = T/T_c$$

γ	$\frac{\Delta H_v}{RT_c}$
0.00000E-99	+ ∞
1.00000E-01	1.61708E+01
1.50000E-01	1.31663E+01
2.00000E-01	1.13622E+01
2.50000E-01	1.01194E+01
3.00000E-01	9.19100E-00
3.50000E-01	8.45837E-00
4.00000E-01	7.85631E-00
4.50000E-01	7.34447E-00
5.00000E-01	6.89449E-00
5.50000E-01	6.48390E-00
6.00000E-01	6.09347E-00
6.50000E-01	5.70618E-00
7.00000E-01	5.30617E-00
7.50000E-01	4.87729E-00
8.00000E-01	4.40064E-00
8.50000E-01	3.84976E-00
9.00000E-01	3.17842E-00
9.50000E-01	2.27423E-00
9.52000E-01	2.22937E-00
9.54000E-01	2.18349E-00
9.56000E-01	2.13653E-00
9.58000E-01	2.08843E-00
9.60000E-01	2.03909E-00
9.62000E-01	1.98844E-00
9.64000E-01	1.93635E-00
9.66000E-01	1.88272E-00
9.68000E-01	1.82740E-00
9.70000E-01	1.77024E-00
9.72000E-01	1.71106E-00
9.74000E-01	1.64963E-00
9.76000E-01	1.58570E-00
9.78000E-01	1.51894E-00
9.80000E-01	1.44897E-00
9.82000E-01	1.37530E-00
9.84000E-01	1.29729E-00
9.86000E-01	1.21411E-00
9.88000E-01	1.12461E-00
9.90000E-01	1.02713E-00
9.92000E-01	9.19157E-01
9.94000E-01	7.96412E-01
9.96000E-01	6.50593E-01
9.98000E-01	4.60269E-01
9.99000E-01	3.25541E-01
1.00000E-00	0.00000E-99

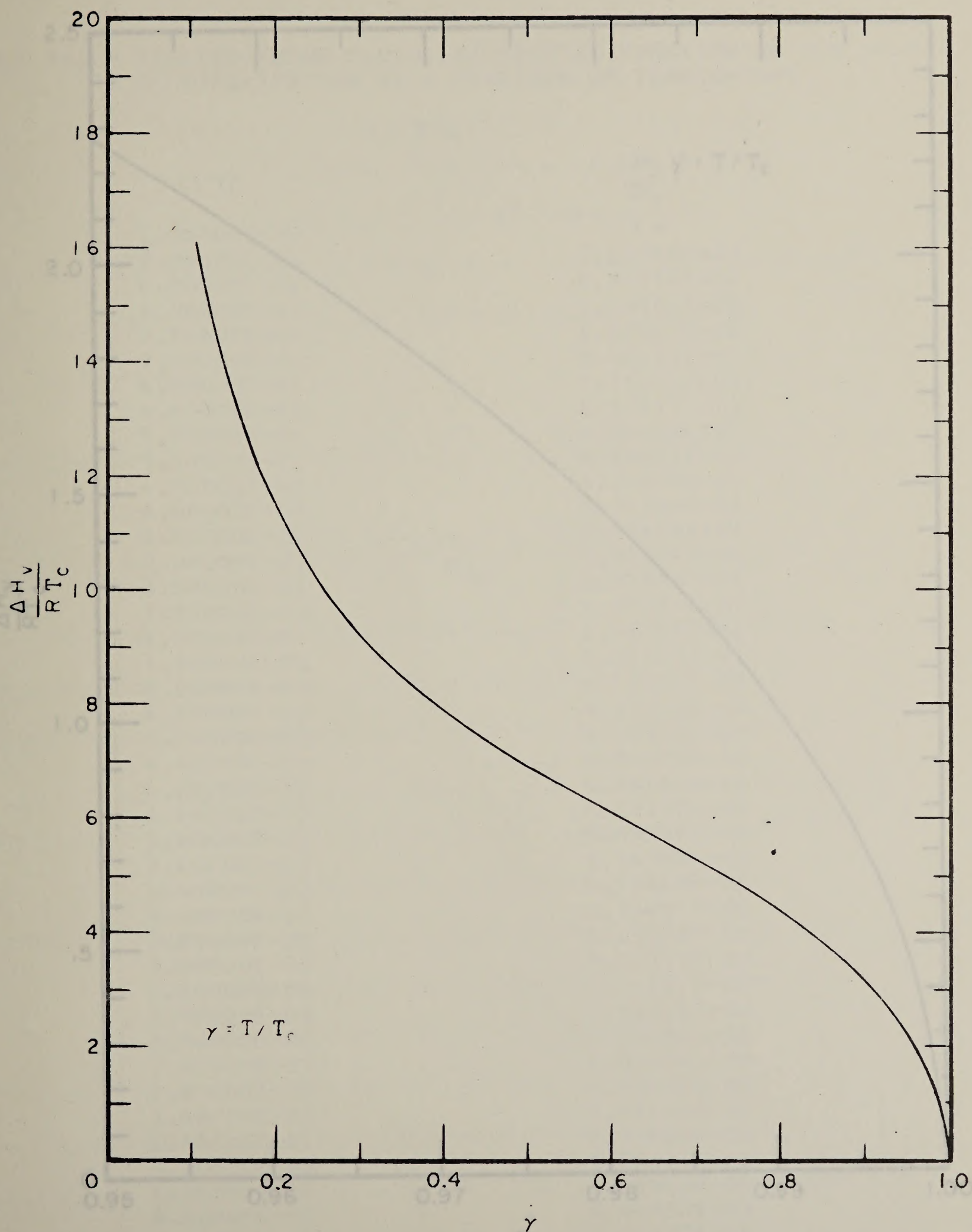


FIGURE 57.—Redlich-Kwong Fluid, Heat of Vaporization as a Function of Temperature.

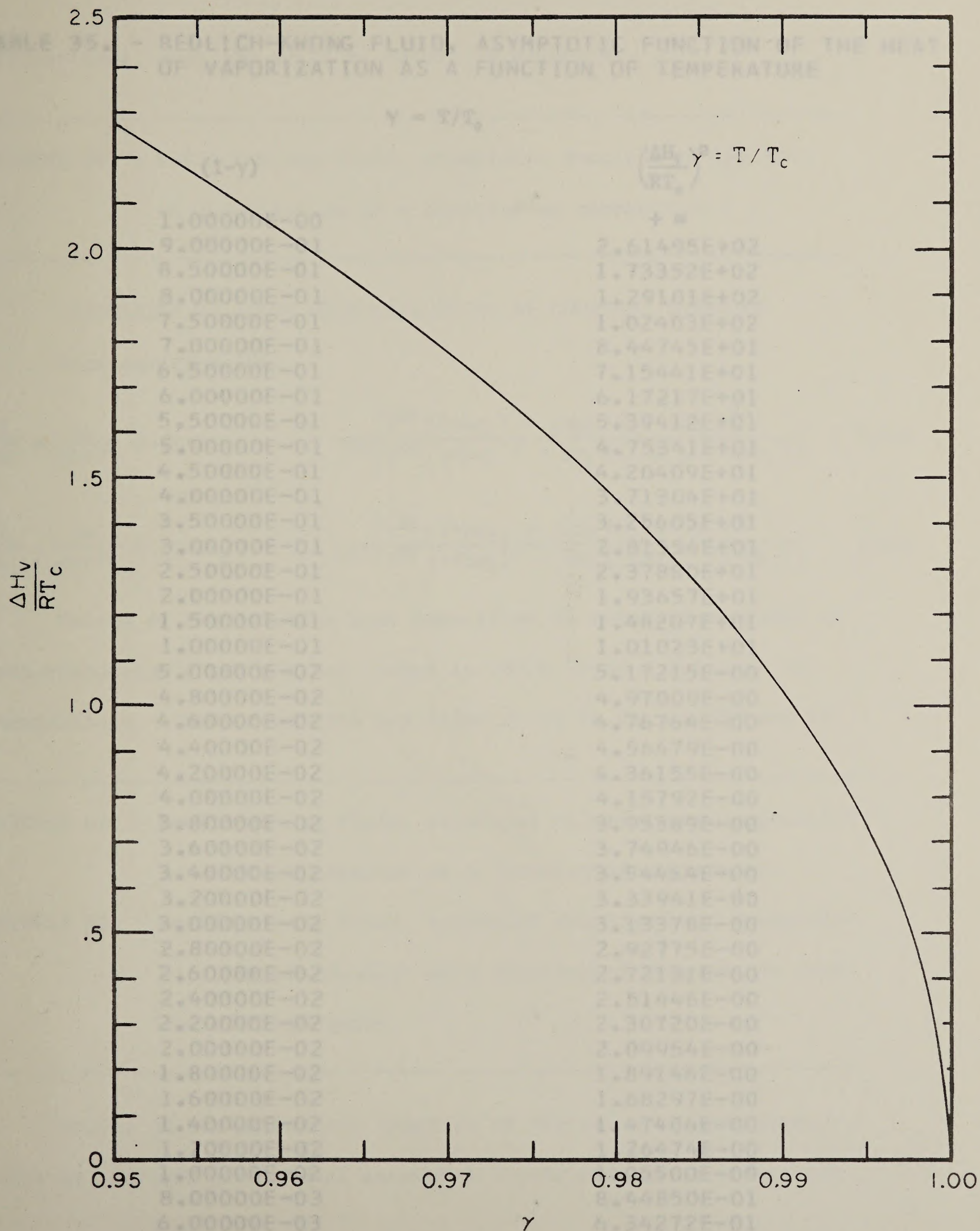


FIGURE 58.— Redlich-Kwong Fluid, Heat of Vaporization as a Function of Temperature Near the Critical Point.

TABLE 35. - REDLICH-KWONG FLUID, ASYMPTOTIC FUNCTION OF THE HEAT OF VAPORIZATION AS A FUNCTION OF TEMPERATURE

$$\gamma = T/T_c$$

(1- γ)	$\left(\frac{\Delta H_v}{RT_c}\right)^2$
1.00000E-00	+ ∞
9.00000E-01	2.61495E+02
8.50000E-01	1.73352E+02
8.00000E-01	1.29101E+02
7.50000E-01	1.02403E+02
7.00000E-01	8.44745E+01
6.50000E-01	7.15441E+01
6.00000E-01	6.17217E+01
5.50000E-01	5.39412E+01
5.00000E-01	4.75341E+01
4.50000E-01	4.20409E+01
4.00000E-01	3.71304E+01
3.50000E-01	3.25605E+01
3.00000E-01	2.81554E+01
2.50000E-01	2.37880E+01
2.00000E-01	1.93657E+01
1.50000E-01	1.48207E+01
1.00000E-01	1.01023E+01
5.00000E-02	5.17215E-00
4.80000E-02	4.97009E-00
4.60000E-02	4.76764E-00
4.40000E-02	4.56479E-00
4.20000E-02	4.36155E-00
4.00000E-02	4.15792E-00
3.80000E-02	3.95389E-00
3.60000E-02	3.74946E-00
3.40000E-02	3.54464E-00
3.20000E-02	3.33941E-00
3.00000E-02	3.13378E-00
2.80000E-02	2.92775E-00
2.60000E-02	2.72131E-00
2.40000E-02	2.51446E-00
2.20000E-02	2.30720E-00
2.00000E-02	2.09954E-00
1.80000E-02	1.89146E-00
1.60000E-02	1.68297E-00
1.40000E-02	1.47406E-00
1.20000E-02	1.26474E-00
1.00000E-02	1.05500E-00
8.00000E-03	8.44850E-01
6.00000E-03	6.34272E-01
4.00000E-03	4.23271E-01
2.00000E-03	2.11848E-01
1.00000E-03	1.05977E-01
0.00000E-99	0.00000E-99

illustrated, near the critical point, in figure 59.

FIGURE 59. - Redlich-Kwong fluid, asymptotic function of the heat of vaporization as a function of temperature.

SATURATED RELATIVE HEAT CAPACITIES AT CONSTANT PRESSURE

From equation 104,

$$\frac{J_1}{R} = \frac{3a}{4b\gamma^{3/2}} \ln(1+b\alpha_1) - 1 + \frac{[\gamma^{3/2}(1+b\alpha_1) + (a\alpha_1/2)(1-b\alpha_1)]^2}{\gamma^{3/2}[\gamma^{3/2}(1+b\alpha_1)^2 - a\alpha_1(1-b\alpha_1)^2(2+b\alpha_1)]} ; \quad (244)$$

$$\frac{J_3}{R} = \frac{3a}{4b\gamma^{3/2}} \ln(1+b\alpha_3) - 1 + \frac{[\gamma^{3/2}(1+b\alpha_3) + (a\alpha_3/2)(1-b\alpha_3)]^2}{\gamma^{3/2}[\gamma^{3/2}(1+b\alpha_3)^2 - a\alpha_3(1-b\alpha_3)^2(2+b\alpha_3)]} . \quad (245)$$

Values of the relative heat capacities at constant pressure of saturated liquid and gas are listed in table 36 as a function of temperature. These same data are illustrated in figures 60 and 61.

FIGURE 60. - Redlich-Kwong fluid, saturated relative heat capacities at constant pressure as a function of temperature.

FIGURE 61. - Redlich-Kwong fluid, saturated relative heat capacities at constant pressure as a function of temperature near the critical point.

Values of the asymptotic function of the relative heat capacities at constant pressure of saturated liquid and gas as a function

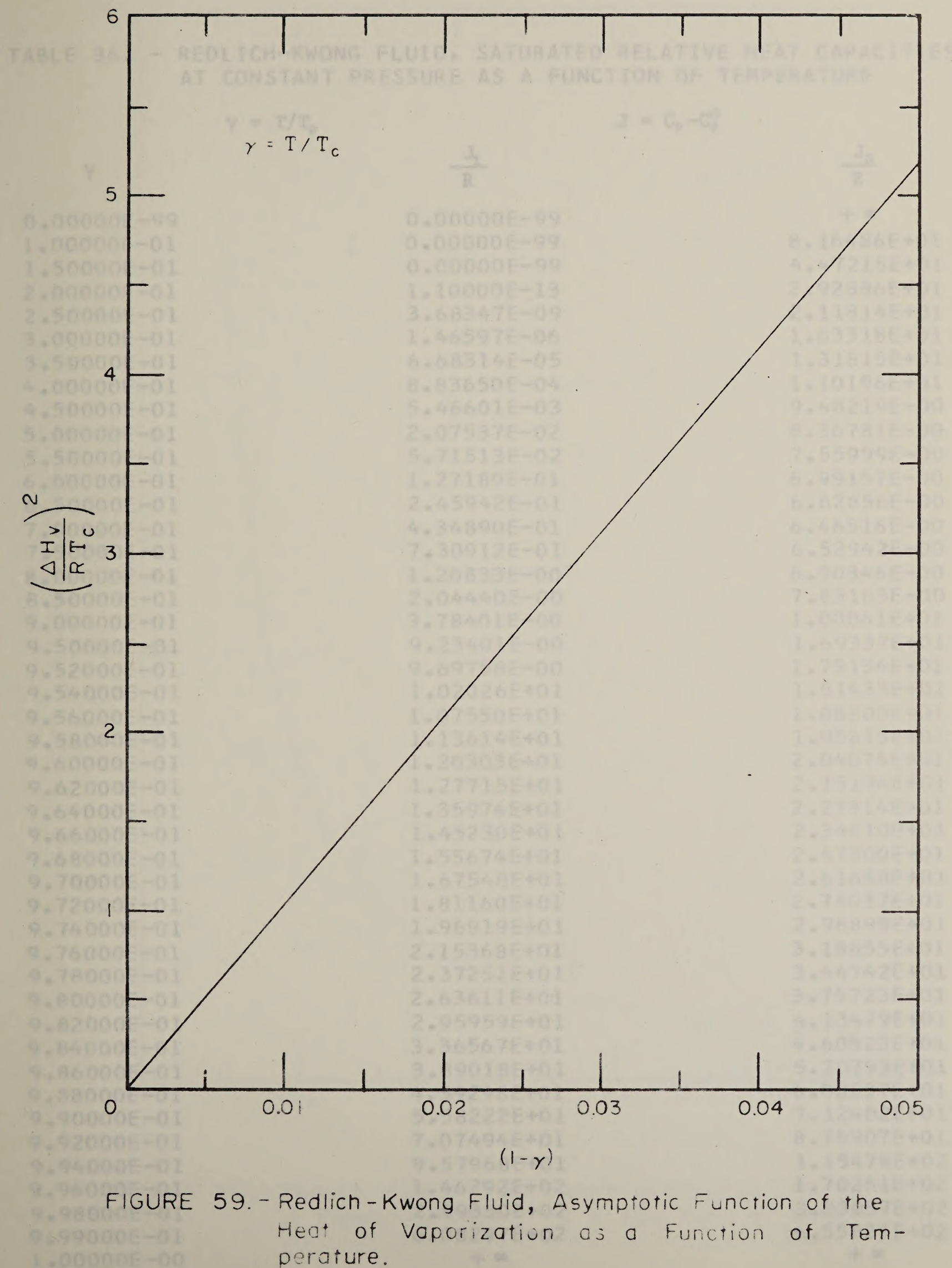


TABLE 36. - REDLICH-KWONG FLUID, SATURATED RELATIVE HEAT CAPACITIES
AT CONSTANT PRESSURE AS A FUNCTION OF TEMPERATURE

$\gamma = T/T_c$	$J = C_p - C_p^0$	
γ	$\frac{J_1}{R}$	$\frac{J_2}{R}$
0.00000E-99	0.00000E-99	+ ∞
1.00000E-01	0.00000E-99	8.16486E+01
1.50000E-01	0.00000E-99	4.47215E+01
2.00000E-01	1.10000E-13	2.92886E+01
2.50000E-01	3.68347E-09	2.11814E+01
3.00000E-01	1.46597E-06	1.63318E+01
3.50000E-01	6.68314E-05	1.31815E+01
4.00000E-01	8.83650E-04	1.10196E+01
4.50000E-01	5.46601E-03	9.48219E-00
5.00000E-01	2.07537E-02	8.36781E-00
5.50000E-01	5.71513E-02	7.55999E-00
6.00000E-01	1.27180E-01	6.99157E-00
6.50000E-01	2.45942E-01	6.62856E-00
7.00000E-01	4.34890E-01	6.46516E-00
7.50000E-01	7.30912E-01	6.52942E-00
8.00000E-01	1.20833E-00	6.90846E-00
8.50000E-01	2.04440E-00	7.83163E-00
9.00000E-01	3.78401E-00	1.00061E+01
9.50000E-01	9.23401E-00	1.69337E+01
9.52000E-01	9.69758E-00	1.75134E+01
9.54000E-01	1.02026E+01	1.81433E+01
9.56000E-01	1.07550E+01	1.88300E+01
9.58000E-01	1.13614E+01	1.95815E+01
9.60000E-01	1.20303E+01	2.04074E+01
9.62000E-01	1.27715E+01	2.13194E+01
9.64000E-01	1.35974E+01	2.23314E+01
9.66000E-01	1.45230E+01	2.34610E+01
9.68000E-01	1.55674E+01	2.47300E+01
9.70000E-01	1.67548E+01	2.61658E+01
9.72000E-01	1.81160E+01	2.78037E+01
9.74000E-01	1.96919E+01	2.96899E+01
9.76000E-01	2.15368E+01	3.18855E+01
9.78000E-01	2.37251E+01	3.44742E+01
9.80000E-01	2.63611E+01	3.75723E+01
9.82000E-01	2.95959E+01	4.13479E+01
9.84000E-01	3.36567E+01	4.60523E+01
9.86000E-01	3.89018E+01	5.20793E+01
9.88000E-01	4.59298E+01	6.00837E+01
9.90000E-01	5.58222E+01	7.12402E+01
9.92000E-01	7.07494E+01	8.78907E+01
9.94000E-01	9.57968E+01	1.15478E+02
9.96000E-01	1.46292E+02	1.70261E+02
9.98000E-01	2.99350E+02	3.33057E+02
9.99000E-01	6.08297E+02	6.55831E+02
1.00000E-00	+ ∞	+ ∞

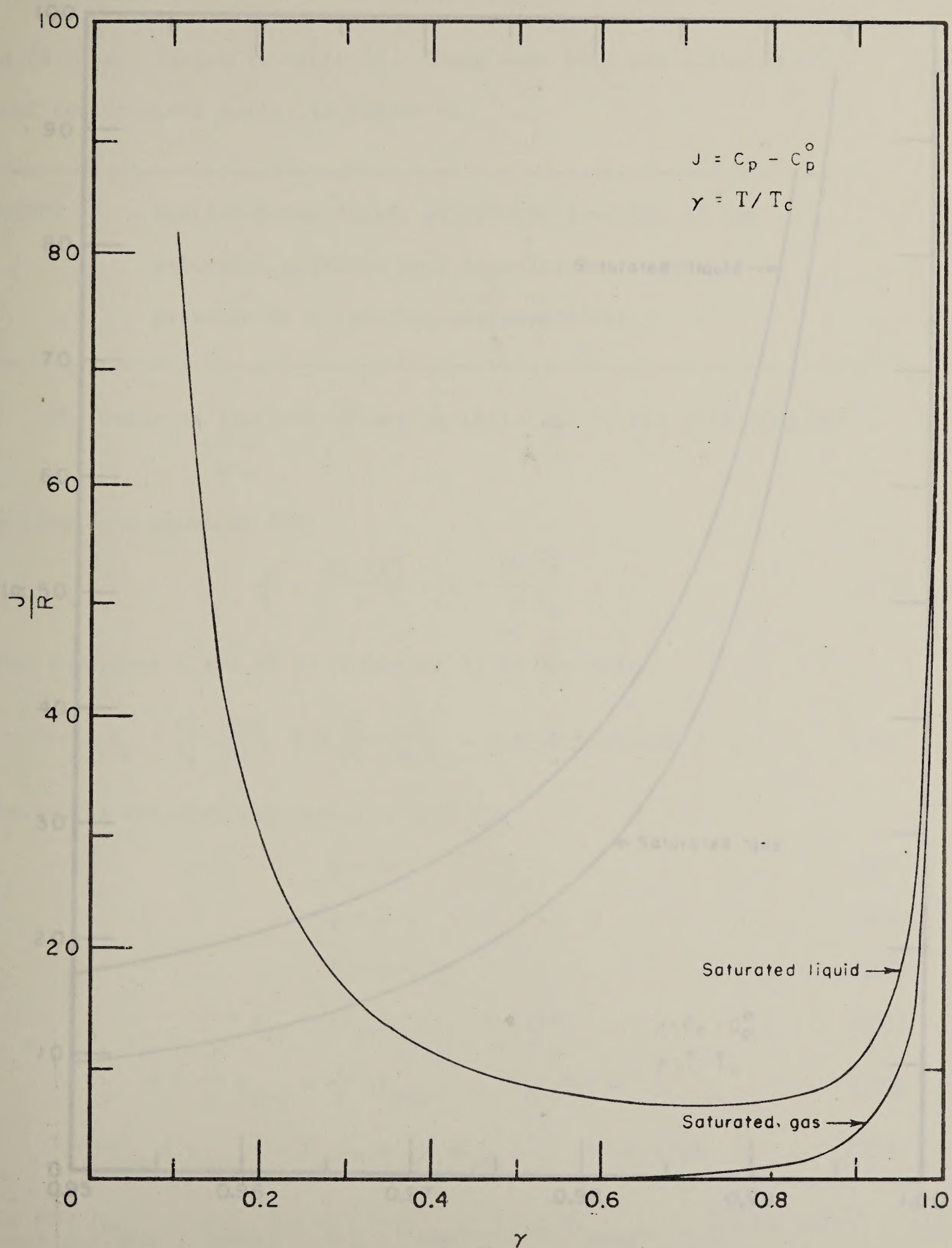


FIGURE 60.—Redlich-Kwong Fluid, Saturated Relative Heat Capacities at Constant Pressure as a Function of Temperature.

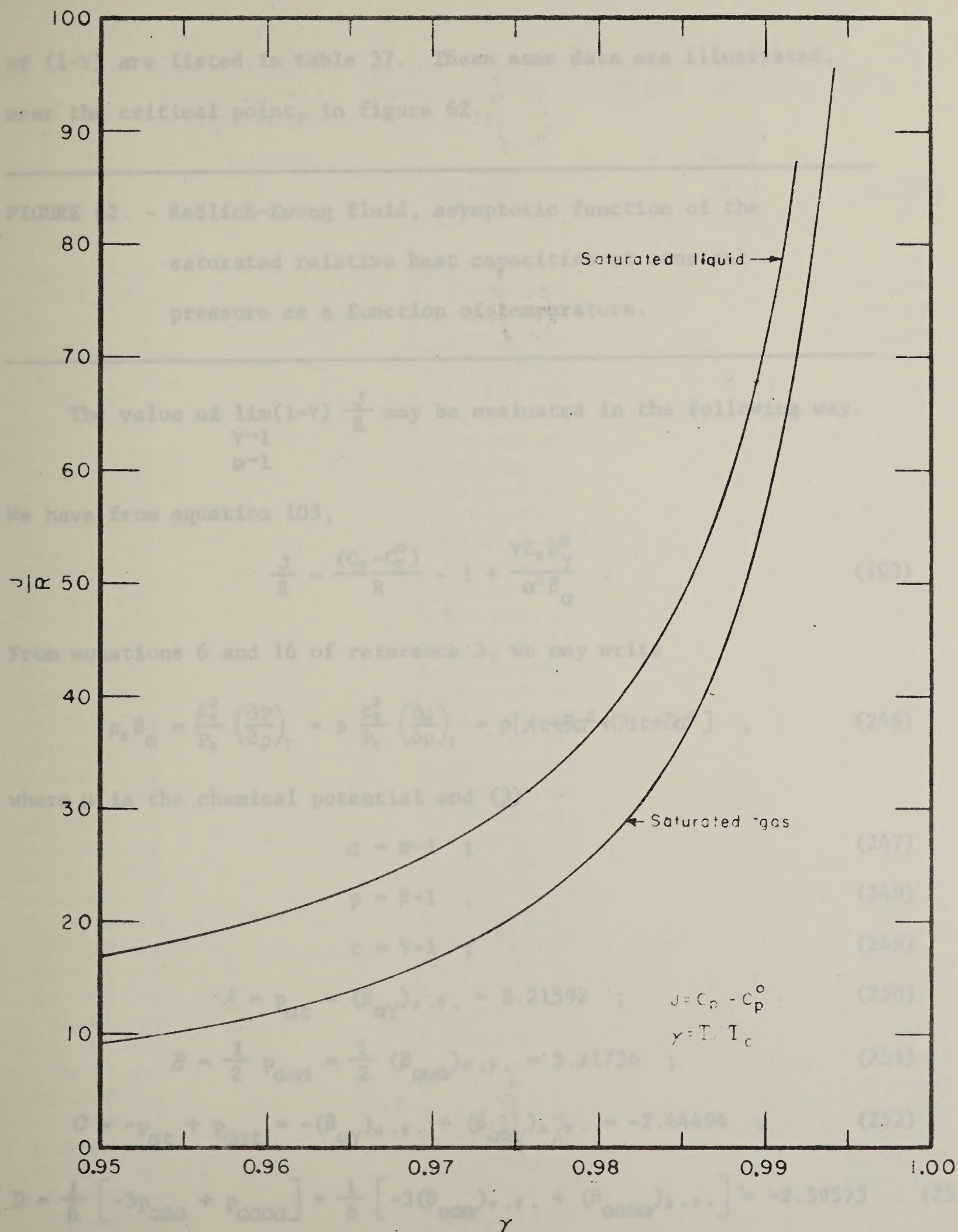


FIGURE 61.—Redlich-Kwong Fluid, Saturated Relative Heat Capacities at Constant Pressure as a Function of Temperature Near the Critical Point.

of $(1-\gamma)$ are listed in table 37. These same data are illustrated, near the critical point, in figure 62.

FIGURE 62. - Redlich-Kwong fluid, asymptotic function of the saturated relative heat capacities at constant pressure as a function of temperature.

The value of $\lim_{\substack{\gamma \rightarrow 1 \\ \alpha \rightarrow 1}} (1-\gamma) \frac{J}{R}$ may be evaluated in the following way.

We have from equation 103,

$$\frac{J}{R} = \frac{(C_V - C_V^0)}{R} - 1 + \frac{\gamma Z_c \beta_Y^2}{\alpha^2 \beta_\alpha} \quad (103)$$

From equations 6 and 16 of reference 3, we may write

$$\rho_c \beta_\alpha = \frac{\rho_c^2}{P_c} \left(\frac{\partial P}{\partial \rho} \right)_T = \rho \frac{\rho_c^2}{P_c} \left(\frac{\partial \mu}{\partial \rho} \right)_T = \rho [A t + B \alpha^2 + C \alpha t + D \alpha^3] \quad (246)$$

where μ is the chemical potential and (3)

$$\alpha = \alpha - 1 \quad ; \quad (247)$$

$$p = \beta - 1 \quad ; \quad (248)$$

$$t = \gamma - 1 \quad ; \quad (249)$$

$$A = p_{\alpha t} = (\beta_{\alpha \gamma})_{c.p.} = 8.21592 \quad ; \quad (250)$$

$$B = \frac{1}{2} p_{aaa} = \frac{1}{2} (\beta_{\alpha \alpha \alpha})_{c.p.} = 3.21736 \quad ; \quad (251)$$

$$C = -p_{\alpha t} + p_{\alpha \alpha t} = -(\beta_{\alpha \gamma})_{c.p.} + (\beta_{\alpha \alpha \gamma})_{c.p.} = -2.44494 \quad ; \quad (252)$$

$$D = \frac{1}{6} [-3p_{aaa} + p_{aaaa}] = \frac{1}{6} [-3(\beta_{\alpha \alpha \alpha})_{c.p.} + (\beta_{\alpha \alpha \alpha \alpha})_{c.p.}] = -2.59573 \quad (253)$$

TABLE 37. - REDLICH-KWONG FLUID, ASYMPTOTIC FUNCTION OF THE SATURATED RELATIVE HEAT CAPACITIES AT CONSTANT PRESSURE AS A FUNCTION OF TEMPERATURE

$\gamma = T/T_c$	$J = C_p - C_p^0$	
(1- γ)	$\frac{(1-\gamma)J_1}{R}$	$\frac{(1-\gamma)J_3}{R}$
1.00000E-00	0.00000E-99	+ ∞
9.00000E-01	0.00000E-99	7.34838E+01
8.50000E-01	0.00000E-99	3.80133E+01
8.00000E-01	8.80000E-14	2.34308E+01
7.50000E-01	2.76260E-09	1.58860E+01
7.00000E-01	1.02618E-06	1.14323E+01
6.50000E-01	4.34404E-05	8.56801E-00
6.00000E-01	5.30190E-04	6.61177E-00
5.50000E-01	3.00630E-03	5.21520E-00
5.00000E-01	1.03768E-02	4.18390E-00
4.50000E-01	2.57180E-02	3.40199E-00
4.00000E-01	5.08723E-02	2.79662E-00
3.50000E-01	8.60797E-02	2.31999E-00
3.00000E-01	1.30467E-01	1.93955E-00
2.50000E-01	1.82728E-01	1.63235E-00
2.00000E-01	2.41667E-01	1.38169E-00
1.50000E-01	3.06660E-01	1.17474E-00
1.00000E-01	3.78401E-01	1.00061E-00
5.00000E-02	4.61700E-01	8.46686E-01
4.80000E-02	4.65484E-01	8.40647E-01
4.60000E-02	4.69322E-01	8.34594E-01
4.40000E-02	4.73220E-01	8.28521E-01
4.20000E-02	4.77182E-01	8.22425E-01
4.00000E-02	4.81213E-01	8.16299E-01
3.80000E-02	4.85319E-01	8.10137E-01
3.60000E-02	4.89507E-01	8.03932E-01
3.40000E-02	4.93784E-01	7.97677E-01
3.20000E-02	4.98159E-01	7.91361E-01
3.00000E-02	5.02644E-01	7.84975E-01
2.80000E-02	5.07249E-01	7.78505E-01
2.60000E-02	5.11990E-01	7.71937E-01
2.40000E-02	5.16884E-01	7.65254E-01
2.20000E-02	5.21953E-01	7.58432E-01
2.00000E-02	5.27222E-01	7.51446E-01
1.80000E-02	5.32726E-01	7.44262E-01
1.60000E-02	5.38508E-01	7.36836E-01
1.40000E-02	5.44625E-01	7.29110E-01
1.20000E-02	5.51158E-01	7.21004E-01
1.00000E-02	5.58222E-01	7.12402E-01
8.00000E-03	5.65995E-01	7.03125E-01
6.00000E-03	5.74781E-01	6.92871E-01
4.00000E-03	5.85170E-01	6.81047E-01
2.00000E-03	5.98701E-01	6.66115E-01
1.00000E-03	6.08297E-01	6.55831E-01
0.00000E-99	6.31724E-01	6.31724E-01

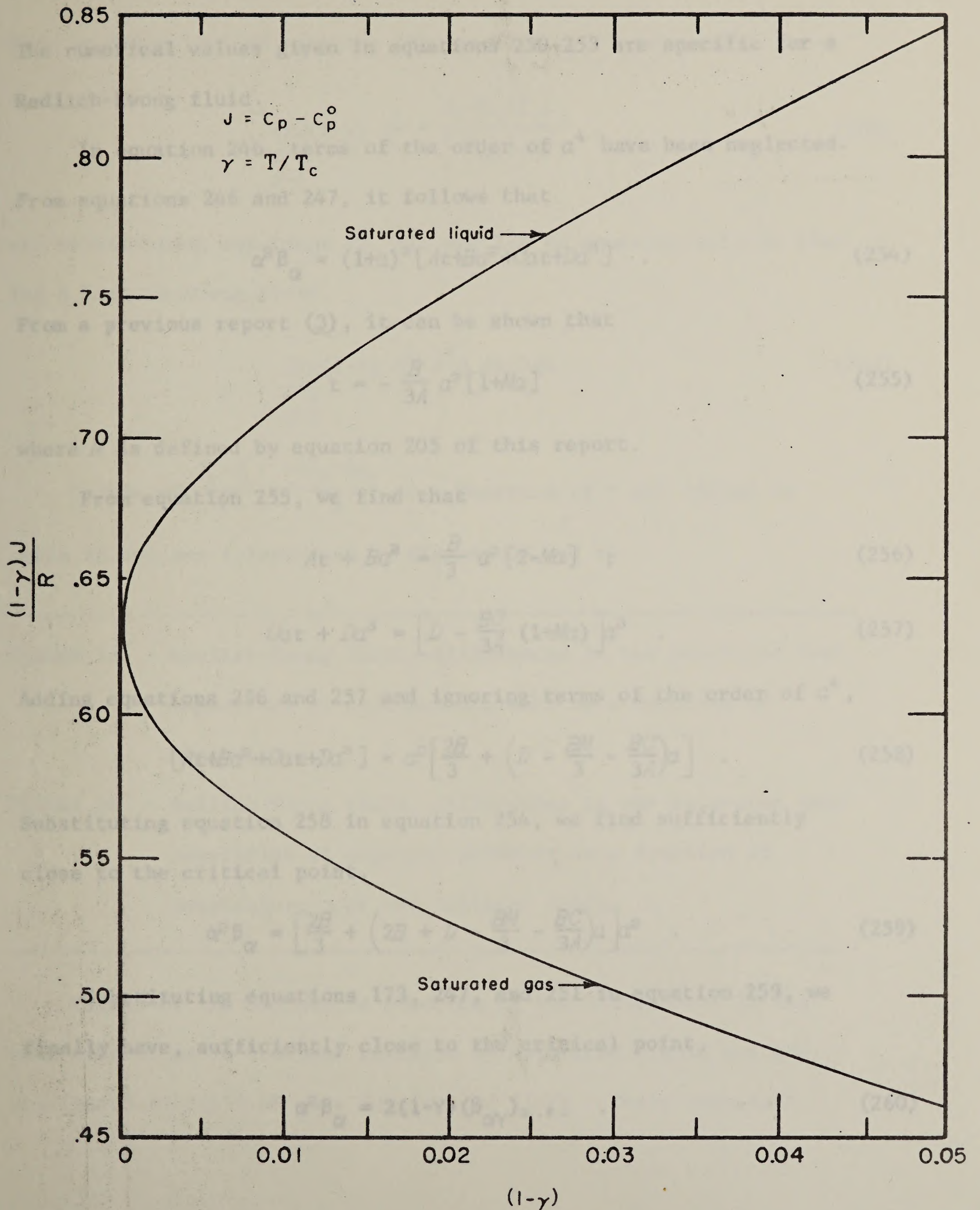


FIGURE 62.- Redlich-Kwong Fluid, Asymptotic Function of the Saturated Relative Heat Capacities at Constant Pressure as a Function of Temperature.

The numerical values given in equations 250-253 are specific for a Redlich-Kwong fluid.

In equation 246, terms of the order of a^4 have been neglected.

From equations 246 and 247, it follows that

$$\alpha^2 \beta_\alpha = (1+a)^3 [At + B\alpha^2 + Ca + D\alpha^3] \quad (254)$$

From a previous report (3), it can be shown that

$$t = -\frac{B}{3A} \alpha^2 [1 + Ma] \quad (255)$$

where M is defined by equation 205 of this report.

From equation 255, we find that

$$At + B\alpha^2 = \frac{B}{3} \alpha^2 [2 - Ma] \quad (256)$$

$$Ca + D\alpha^3 = \left[D - \frac{BC}{3A} (1 + Ma) \right] \alpha^3 \quad (257)$$

Adding equations 256 and 257 and ignoring terms of the order of a^4 ,

$$[At + B\alpha^2 + Ca + D\alpha^3] = \alpha^2 \left[\frac{2B}{3} + \left(D - \frac{BM}{3} - \frac{BC}{3A} \right) \alpha \right] \quad (258)$$

Substituting equation 258 in equation 254, we find sufficiently close to the critical point,

$$\alpha^2 \beta_\alpha = \left[\frac{2B}{3} + \left(2B + D - \frac{BM}{3} - \frac{BC}{3A} \right) \alpha \right] \alpha^2 \quad (259)$$

Substituting equations 173, 247, and 251 in equation 259, we finally have, sufficiently close to the critical point,

$$\alpha^2 \beta_\alpha = 2(1-\gamma) (\beta_{\alpha\gamma})_{c.p.} \quad (260)$$

From equation 260 and equation 103, we find

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha \rightarrow 1}} (1-\gamma) \frac{J}{R} = \frac{Z_c (\beta_\gamma)_{c.p.}^2}{2(\beta_{\alpha\gamma})_{c.p.}} \quad (261)$$

or, substituting equations 23, 51, and 178 in equation 261, we find for a Redlich-Kwong fluid,

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha \rightarrow 1}} (1-\gamma) \frac{J}{R} = 0.631724 \quad (262)$$

Values of $\frac{J_3 - J_1}{R} = \frac{C_{p3} - C_{p1}}{R}$ as a function of γ are listed in

table 38 and are illustrated in figures 63 and 64.

FIGURE 63. - Redlich-Kwong fluid, differences in the saturated heat capacities at constant pressure as a function of temperature.

FIGURE 64. - Redlich-Kwong fluid, differences in the saturated heat capacities at constant pressure as a function of temperature near the critical point.

Values of the asymptotic function of the differences in the heat capacities at constant pressure of saturated liquid and gas are listed in table 39 as a function of $(1-\gamma)$. These same data,

TABLE 38. - REDLICH-KWONG FLUID, DIFFERENCES IN THE SATURATED HEAT CAPACITIES AT CONSTANT PRESSURE AS A FUNCTION OF TEMPERATURE

$\gamma = T/T_c$	$J = C_p - C_p^0$
γ	$\frac{J_3 - J_1}{R}$
0.00000E-99	+ ∞
1.00000E-01	8.16486E+01
1.50000E-01	4.47215E+01
2.00000E-01	2.92886E+01
2.50000E-01	2.11814E+01
3.00000E-01	1.63318E+01
3.50000E-01	1.31814E+01
4.00000E-01	1.10187E+01
4.50000E-01	9.47672E-00
5.00000E-01	8.34706E-00
5.50000E-01	7.50284E-00
6.00000E-01	6.86439E-00
6.50000E-01	6.38262E-00
7.00000E-01	6.03027E-00
7.50000E-01	5.79851E-00
8.00000E-01	5.70012E-00
8.50000E-01	5.78722E-00
9.00000E-01	6.22217E-00
9.50000E-01	7.69972E-00
9.52000E-01	7.81591E-00
9.54000E-01	7.94069E-00
9.56000E-01	8.07503E-00
9.58000E-01	8.22007E-00
9.60000E-01	8.37714E-00
9.62000E-01	8.54784E-00
9.64000E-01	8.73404E-00
9.66000E-01	8.93802E-00
9.68000E-01	9.16255E-00
9.70000E-01	9.41103E-00
9.72000E-01	9.68771E-00
9.74000E-01	9.99796E-00
9.76000E-01	1.03487E+01
9.78000E-01	1.07490E+01
9.80000E-01	1.12112E+01
9.82000E-01	1.17520E+01
9.84000E-01	1.23955E+01
9.86000E-01	1.31775E+01
9.88000E-01	1.41538E+01
9.90000E-01	1.54179E+01
9.92000E-01	1.71412E+01
9.94000E-01	1.96817E+01
9.96000E-01	2.39694E+01
9.98000E-01	3.37067E+01
9.99000E-01	4.75335E+01
1.00000E-00	+ ∞

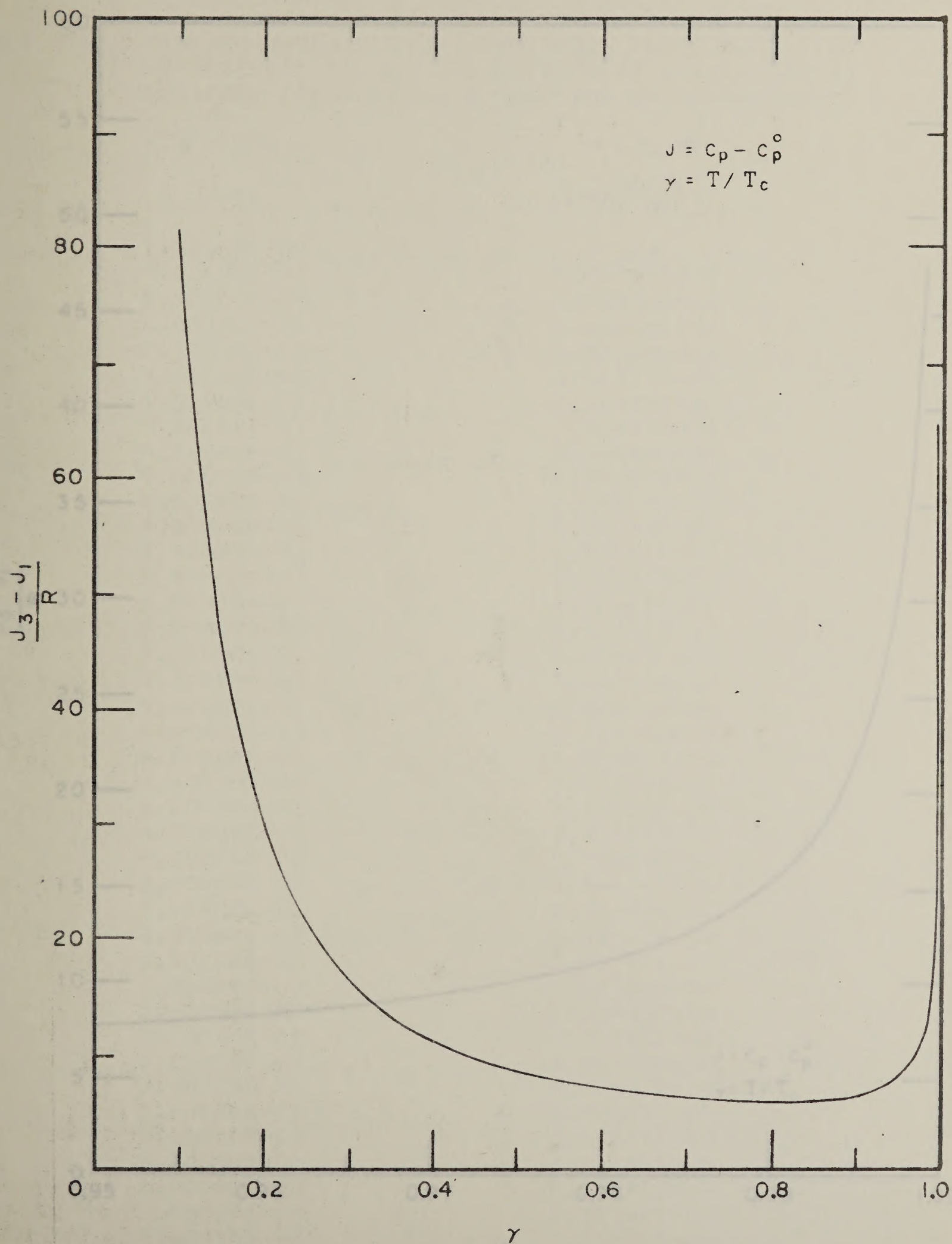


FIGURE 63. — Redlich-Kwong Fluid, Differences in the Saturated Heat Capacities at Constant Pressure as a Function of Temperature.

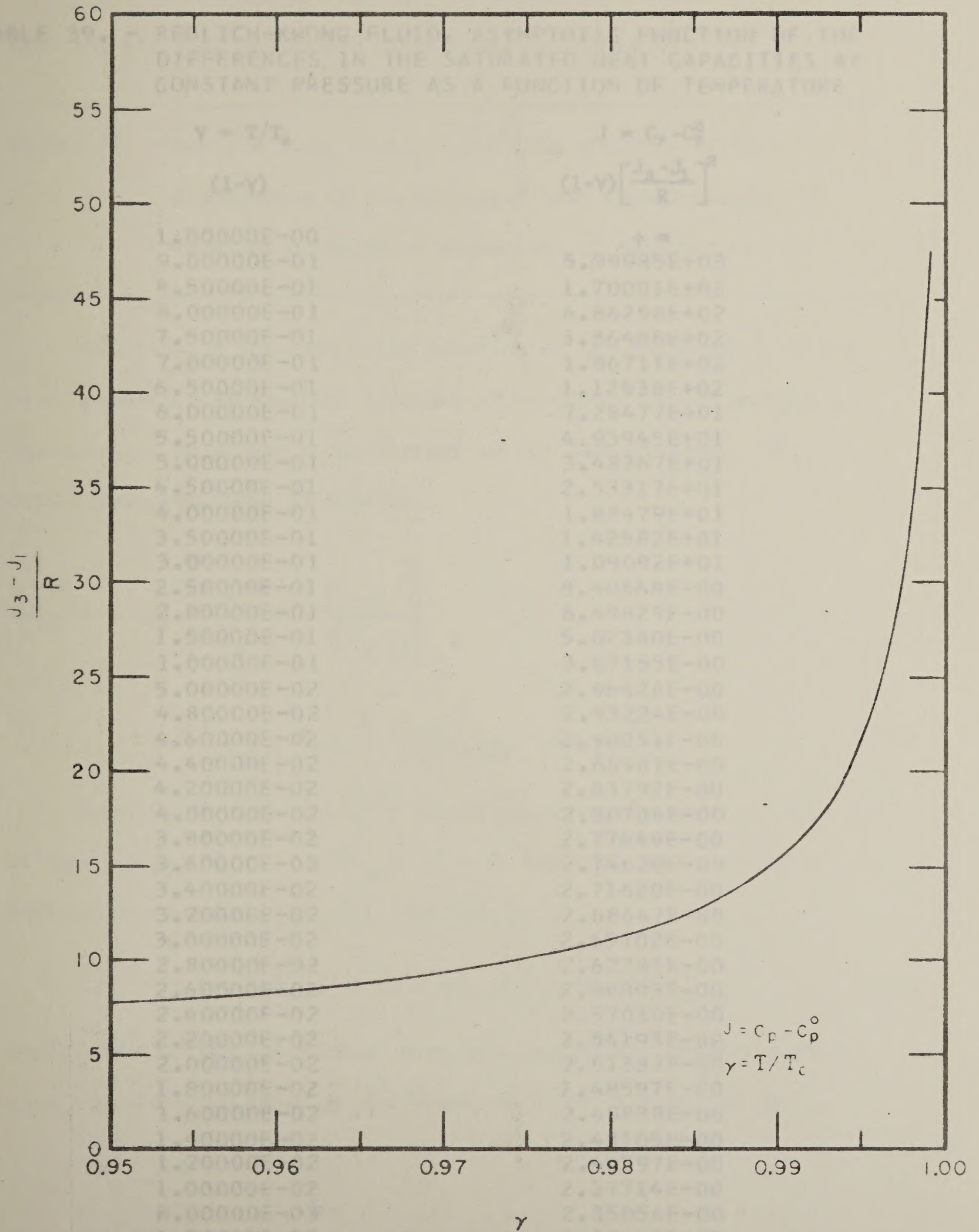


FIGURE 64.—Redlich-Kwong Fluid, Differences in the Saturated Heat Capacities at Constant Pressure as a Function of Temperature Near the Critical Point.

TABLE 39. - REDLICH-KWONG FLUID, ASYMPTOTIC FUNCTION OF THE DIFFERENCES IN THE SATURATED HEAT CAPACITIES AT CONSTANT PRESSURE AS A FUNCTION OF TEMPERATURE

$\gamma = T/T_c$	$J = C_p - C_p^0$
$(1-\gamma)$	$(1-\gamma) \left[\frac{J_3 - J_1}{R} \right]^2$
1.00000E-00	+ ∞
9.00000E-01	5.99985E+03
8.50000E-01	1.70001E+03
8.00000E-01	6.86258E+02
7.50000E-01	3.36488E+02
7.00000E-01	1.86711E+02
6.50000E-01	1.12938E+02
6.00000E-01	7.28477E+01
5.50000E-01	4.93945E+01
5.00000E-01	3.48367E+01
4.50000E-01	2.53317E+01
4.00000E-01	1.88479E+01
3.50000E-01	1.42582E+01
3.00000E-01	1.09092E+01
2.50000E-01	8.40568E-00
2.00000E-01	6.49829E-00
1.50000E-01	5.02380E-00
1.00000E-01	3.87155E-00
5.00000E-02	2.96428E-00
4.80000E-02	2.93224E-00
4.60000E-02	2.90051E-00
4.40000E-02	2.86907E-00
4.20000E-02	2.83792E-00
4.00000E-02	2.80706E-00
3.80000E-02	2.77649E-00
3.60000E-02	2.74620E-00
3.40000E-02	2.71620E-00
3.20000E-02	2.68647E-00
3.00000E-02	2.65702E-00
2.80000E-02	2.62785E-00
2.60000E-02	2.59893E-00
2.40000E-02	2.57030E-00
2.20000E-02	2.54193E-00
2.00000E-02	2.51382E-00
1.80000E-02	2.48597E-00
1.60000E-02	2.45838E-00
1.40000E-02	2.43105E-00
1.20000E-02	2.40397E-00
1.00000E-02	2.37714E-00
8.00000E-03	2.35056E-00
6.00000E-03	2.32423E-00
4.00000E-03	2.29813E-00
2.00000E-03	2.27228E-00
1.00000E-03	2.25943E-00
0.00000E-99	2.24668E-00

near the critical point, are illustrated in figure 65.

FIGURE 65. - Redlich-Kwong fluid, asymptotic function of the differences in the saturated heat capacities at constant pressure as a function of temperature.

The value of the asymptotic function of the differences in the heat capacities at constant pressure of saturated liquid and gas at the critical point may be determined in the following way. We obtain from equations 87 and 103,

$$\frac{C_{p3} - C_{p1}}{R} = \gamma Z_c \left[\frac{\beta_{\gamma(3)}^2}{\alpha_3^2 \beta_{\alpha(3)}} - \frac{\beta_{\gamma(1)}^2}{\alpha_1^2 \beta_{\alpha(1)}} \right] - \gamma \left[2(X_{\gamma(3)} - X_{\gamma(1)}) + \gamma(X_{\gamma\gamma(3)} - X_{\gamma\gamma(1)}) \right] \quad (263)$$

Expanding β_{γ} in a Taylor's series about the critical point, we have since, $(\beta_{\alpha})_{c.p.} = (\beta_{\alpha\alpha})_{c.p.} = 0$, and with A , B , and C as defined in equations 250, 251, and 252,

$$\beta_{\gamma} = (\beta_{\gamma})_{c.p.} + Aa + t(\beta_{\gamma\gamma})_{c.p.} + a^2 \left(\frac{A+C}{2} \right) \quad (264)$$

where terms of the order of t^2 have been neglected. Squaring equation 264, ignoring terms of the order of a^3 and higher, we get

FIGURE 65. - Redlich-Kwong Fluid, Asymptotic Function of the Differences in the Saturated Heat Capacities at Constant Pressure as a Function of Temperature.

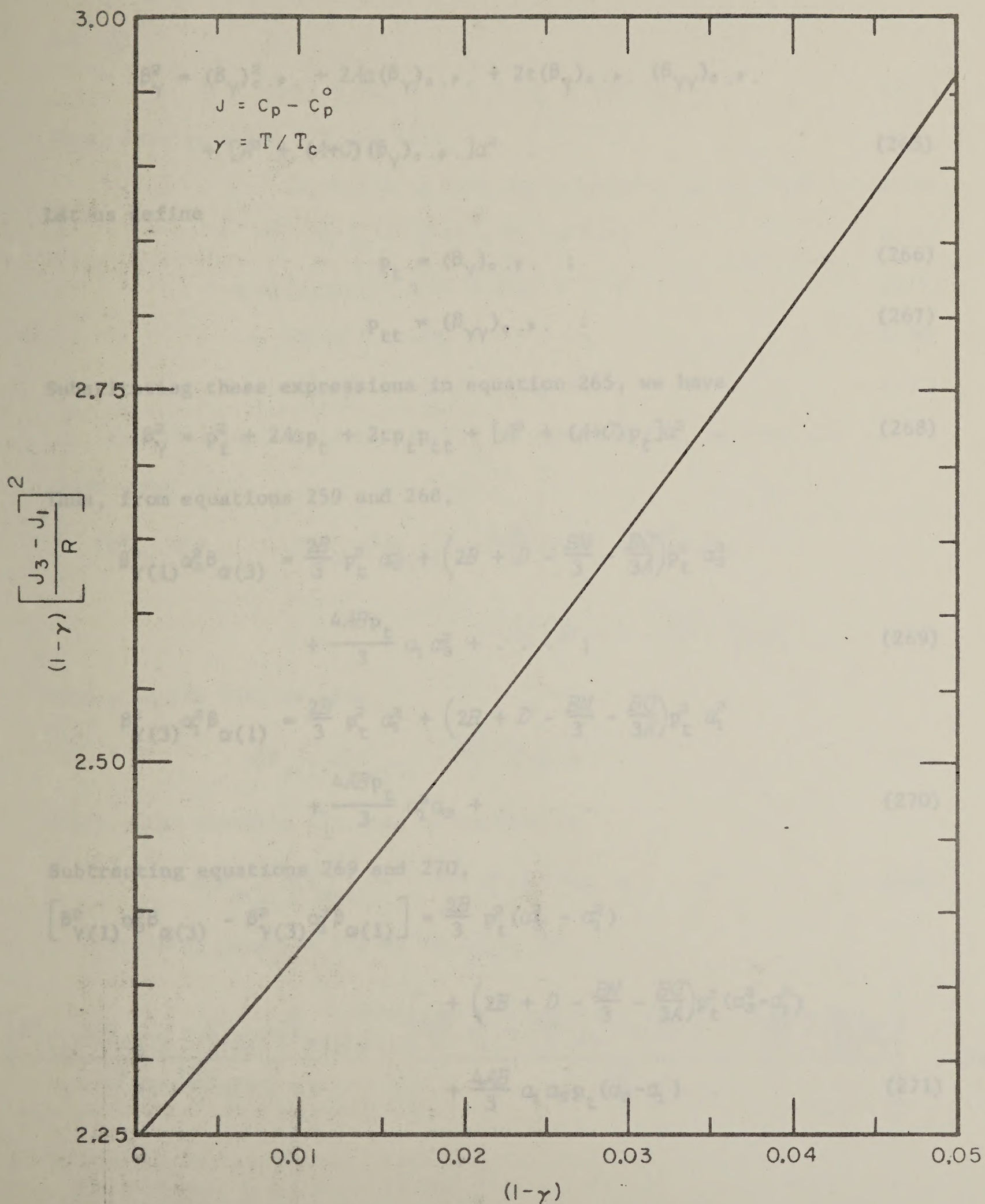


FIGURE 65. — Redlich-Kwong Fluid, Asymptotic Function of the Differences in the Saturated Heat Capacities at Constant Pressure as a Function of Temperature.

$$\beta_Y^2 = (\beta_Y)_{c.p.}^2 + 2Aa(\beta_Y)_{c.p.} + 2t(\beta_Y)_{c.p.} (\beta_{YY})_{c.p.}$$

$$+ [A^2 + (A+C)(\beta_Y)_{c.p.}]a^2 \quad (265)$$

Let us define

$$p_t = (\beta_Y)_{c.p.} \quad ; \quad (266)$$

$$p_{tt} = (\beta_{YY})_{c.p.} \quad (267)$$

Substituting these expressions in equation 265, we have

$$\beta_Y^2 = p_t^2 + 2Aap_t + 2tp_t p_{tt} + [A^2 + (A+C)p_t]a^2 \quad (268)$$

Thus, from equations 259 and 268,

$$\begin{aligned} \beta_{Y(1)}^2 \alpha_3^2 \beta_{\alpha(3)} &= \frac{2B}{3} p_t^2 a_3^2 + \left(2B + D - \frac{BM}{3} - \frac{BC}{3A}\right) p_t^2 a_3^3 \\ &+ \frac{4ABp_t}{3} a_1 a_3^2 + \dots \quad ; \end{aligned} \quad (269)$$

$$\begin{aligned} \beta_{Y(3)}^2 \alpha_1^2 \beta_{\alpha(1)} &= \frac{2B}{3} p_t^2 a_1^2 + \left(2B + D - \frac{BM}{3} - \frac{BC}{3A}\right) p_t^2 a_1^3 \\ &+ \frac{4ABp_t}{3} a_1^2 a_3 + \dots \end{aligned} \quad (270)$$

Subtracting equations 269 and 270,

$$\begin{aligned} \left[\beta_{Y(1)}^2 \alpha_3^2 \beta_{\alpha(3)} - \beta_{Y(3)}^2 \alpha_1^2 \beta_{\alpha(1)} \right] &= \frac{2B}{3} p_t^2 (a_3^2 - a_1^2) \\ &+ \left(2B + D - \frac{BM}{3} - \frac{BC}{3A}\right) p_t^2 (a_3^3 - a_1^3) \\ &+ \frac{4AB}{3} a_1 a_3 p_t (a_3 - a_1) \quad (271) \end{aligned}$$

But (3)

$$a_3 = -a_1 (1 + Ma_1 + \dots) = -a_1 - Ma_1^2 - \dots \quad (272)$$

Thus, from equation 272, we find

$$(a_3 - a_1) = -a_1 (2 + Ma_1 + \dots) \quad (273)$$

$$a_1 a_3 = -a_1^2 (1 + Ma_1 + \dots) \quad (274)$$

$$a_1 a_3 (a_3 - a_1) = a_1^3 (2 + 3Ma_1 + \dots) \quad (275)$$

$$(a_3^2 - a_1^2) = 2Ma_1^3 + \dots \quad (276)$$

$$(a_3^3 - a_1^3) = -a_1^3 (2 + 3Ma_1 + \dots) \quad (277)$$

Substituting equations 275-277 in equation 271, we have to third-order in a ,

$$\begin{aligned} [\beta_{\gamma(1)}^2 \alpha_{\alpha(3)}^2 \beta_{\alpha(3)} - \beta_{\gamma(3)}^2 \alpha_{\alpha(1)}^2 \beta_{\alpha(1)}] &= \frac{4BM}{3} a_1^3 p_t^2 + \frac{8AB}{3} a_1^3 p_t \\ &\quad - 2a_1^3 \left(2B + D - \frac{BM}{3} - \frac{BC}{3A} \right) p_t^2 \quad (278) \end{aligned}$$

From equation 259, we have

$$\alpha_{\alpha(1)}^2 \beta_{\alpha(1)} \alpha_{\alpha(3)}^2 \beta_{\alpha(3)} = \frac{4B^2}{9} a_1^2 a_3^2 + \dots \quad (279)$$

which, from equation 274, can be written as

$$\alpha_{\alpha(1)}^2 \beta_{\alpha(1)} \alpha_{\alpha(3)}^2 \beta_{\alpha(3)} = -\frac{4B^2}{9} a_1^4 (1 + Ma_1 + \dots)^2 \quad (280)$$

Dividing equation 278 by equation 280,

$$\frac{[\beta_{\gamma(1)}^2 \alpha_{\alpha(3)}^2 \beta_{\alpha(3)} - \beta_{\gamma(3)}^2 \alpha_{\alpha(1)}^2 \beta_{\alpha(1)}]}{\alpha_{\alpha(1)}^2 \beta_{\alpha(1)} \alpha_{\alpha(3)}^2 \beta_{\alpha(3)}} = \frac{\left[\frac{4BM}{3} p_t^2 + \frac{8AB}{3} p_t - 2 \left(2B + D - \frac{BM}{3} - \frac{BC}{3A} \right) p_t^2 \right]}{\frac{4B^2}{9} (-a_1)} \quad (281)$$

From equation 255, we have to second order,

$$-\alpha_1 = \left(\frac{-3At}{B}\right)^{1/2} \left[1 - \frac{M}{2} \alpha_1\right] \quad (282)$$

Substituting equations 23, 249, 281, and 282 in equation 263,

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha_1 \rightarrow 1 \\ \alpha_3 \rightarrow 1}} \left[(1-\gamma)^{1/2} \left(\frac{C_{p3} - C_{p1}}{R} \right) \right] = \frac{3^{3/2} p_t Z_c}{4B^{3/2} A^{1/2}} \left[\frac{8AB}{3} + \frac{4BM}{3} p_t - 2 \left(2B + D - \frac{BM}{3} - \frac{BC}{3A} \right) p_t \right] \quad (283)$$

or, squaring equation 283, we have

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha_1 \rightarrow 1 \\ \alpha_3 \rightarrow 1}} \left[(1-\gamma) \left(\frac{C_{p3} - C_{p1}}{R} \right)^2 \right] = \frac{27 p_t^2 Z_c^2}{16AB^3} \left[\frac{8AB}{3} + \frac{4BM}{3} p_t - 2 \left(2B + D - \frac{BM}{3} - \frac{BC}{3A} \right) p_t \right]^2 \quad (284)$$

$$= \frac{27 p_t^2 Z_c^2}{16AB^3} \left[\frac{8AB}{3} - 2 \left(2B + D - \frac{BM}{3} - \frac{BC}{3A} \right) p_t \right]^2$$

The expression given above is true for any analytical fluid.

For a Redlich-Kwong fluid, we then have from equations 23, 51, 206,

250-253, 266, and 284,

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha_1 \rightarrow 1 \\ \alpha_3 \rightarrow 1}} \left[(1-\gamma) \left(\frac{C_{p3} - C_{p1}}{R} \right)^2 \right] = 2.24668 \quad (285)$$

A. FUNCTION RELATED TO THE HEAT OF VAPORIZATION, NAMELY THE HEAT OF VAPORIZATION PER MOLE OF GAS COLLECTED OUTSIDE THE CALORIMETER

In a previous report (5), it is shown that

$$\frac{\Delta H_a}{RT_c} = \frac{\gamma Z_c}{\alpha_1} \beta' , \quad (286)$$

where ΔH_a is the heat of vaporization per mole of gas collected outside the calorimeter. Substituting equations 23 and 194 in the above expression,

$$\frac{\Delta H_a}{RT_c} = \frac{\alpha_3 \gamma}{\alpha_1} \left[\frac{1}{(1-b\alpha_3)} - \frac{a\alpha_3}{\gamma^{3/2} (1+b\alpha_3)} - \frac{3a\alpha_1}{2b\gamma^{3/2} (\alpha_3 - \alpha_1)} \ln \frac{(1+b\alpha_1)}{(1+b\alpha_3)} \right] . \quad (287)$$

At the critical point,

$$\left[\frac{\Delta H_a}{RT_c} \right]_{c.p.} = Z_c (\beta')_{c.p.} = 1.86014 . \quad (288)$$

Values of $\frac{\Delta H_a}{RT_c}$ as a function of γ are listed in table 40.

These same data are illustrated in figures 66 and 67.

FIGURE 66. - Redlich-Kwong fluid, heat of vaporization per mole of gas collected outside the calorimeter as a function of temperature.

FIGURE 67. - Redlich-Kwong fluid, heat of vaporization per mole of gas collected outside the calorimeter as a function of temperature near the critical point.

Values of the asymptotic function of the heat of vaporization per mole of gas collected outside the calorimeter are listed in table 41 as a function of temperature. These data are illustrated,

TABLE 40. - REDLICH-KWONG FLUID, HEAT OF VAPORIZATION PER MOLE OF GAS COLLECTED OUTSIDE THE CALORIMETER AS A FUNCTION OF TEMPERATURE

$\gamma = T/T_c$	$\alpha = p/p_c$	$\Delta H_a = \Delta H_v \alpha_3 / (\alpha_3 - \alpha_1)$
γ		$\frac{\Delta H_a}{RT_c}$
0.00000E-99		$+\infty$
1.00000E-01		1.61708E+01
1.50000E-01		1.31663E+01
2.00000E-01		1.13622E+01
2.50000E-01		1.01194E+01
3.00000E-01		9.19100E-00
3.50000E-01		8.45838E-00
4.00000E-01		7.85642E-00
4.50000E-01		7.34522E-00
5.00000E-01		6.89771E-00
5.50000E-01		6.49370E-00
6.00000E-01		6.11717E-00
6.50000E-01		5.75487E-00
7.00000E-01		5.39534E-00
7.50000E-01		5.02783E-00
8.00000E-01		4.64080E-00
8.50000E-01		4.21935E-00
9.00000E-01		3.73902E-00
9.50000E-01		3.14248E-00
9.52000E-01		3.11425E-00
9.54000E-01		3.08553E-00
9.56000E-01		3.05626E-00
9.58000E-01		3.02641E-00
9.60000E-01		2.99595E-00
9.62000E-01		2.96483E-00
9.64000E-01		2.93299E-00
9.66000E-01		2.90038E-00
9.68000E-01		2.86692E-00
9.70000E-01		2.83254E-00
9.72000E-01		2.79714E-00
9.74000E-01		2.76062E-00
9.76000E-01		2.72285E-00
9.78000E-01		2.68366E-00
9.80000E-01		2.64287E-00
9.82000E-01		2.60022E-00
9.84000E-01		2.55539E-00
9.86000E-01		2.50799E-00
9.88000E-01		2.45741E-00
9.90000E-01		2.40286E-00
9.92000E-01		2.34304E-00
9.94000E-01		2.27584E-00
9.96000E-01		2.19710E-00
9.98000E-01		2.09611E-00
9.99000E-01		2.02583E-00
1.00000E-00		1.86014E-00

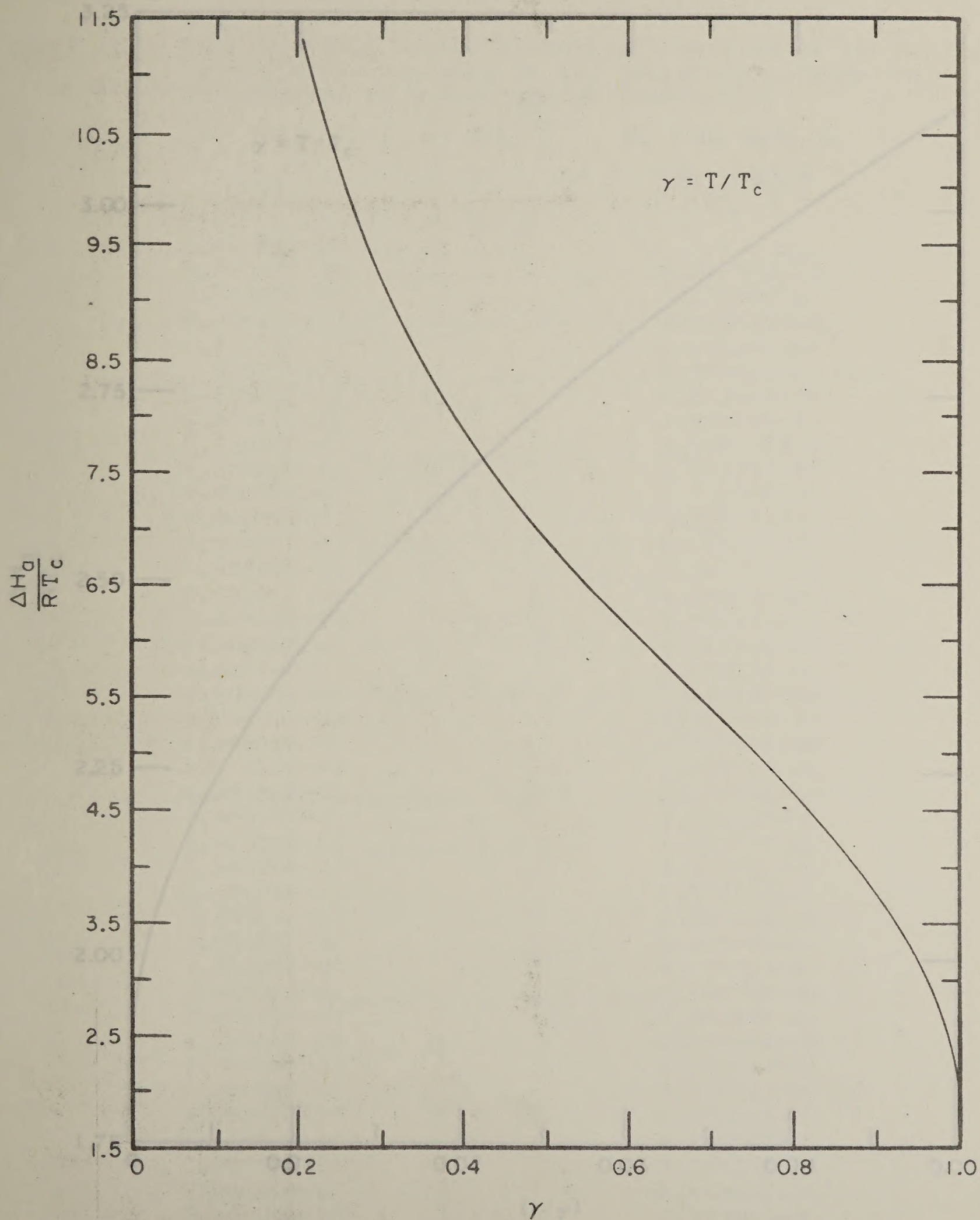


FIGURE 66.— Redlich-Kwong Fluid, Heat of Vaporization Per Mole of Gas Collected Outside the Calorimeter as a Function of Temperature.

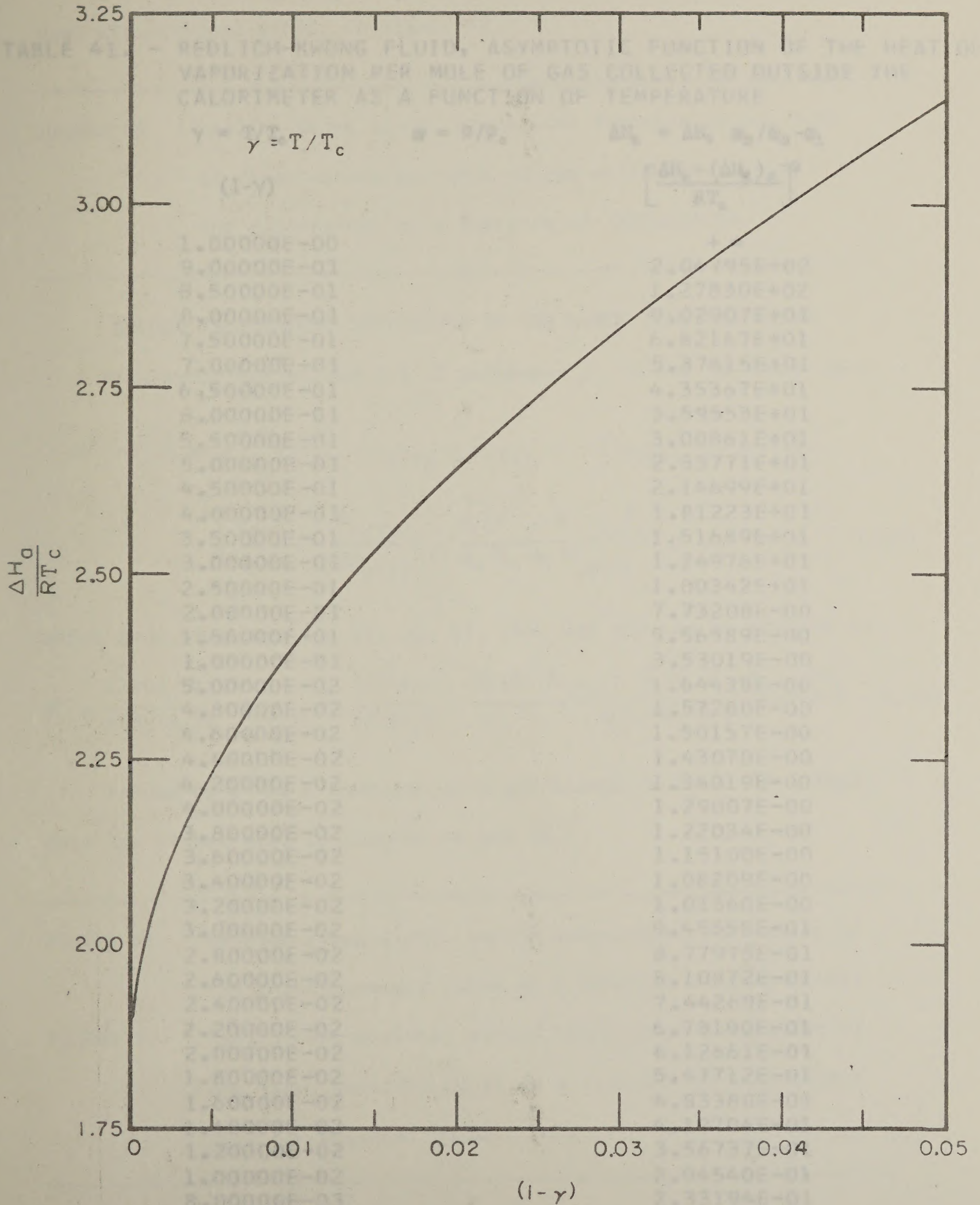


FIGURE 67.—Redlich-Kwong Fluid, Heat of Vaporization Per Mole of Gas Collected Outside the Calorimeter as a Function of Temperature Near the Critical Point.

TABLE 41. - REDLICH-KWONG FLUID, ASYMPTOTIC FUNCTION OF THE HEAT OF VAPORIZATION PER MOLE OF GAS COLLECTED OUTSIDE THE CALORIMETER AS A FUNCTION OF TEMPERATURE

$\gamma = T/T_c$	$\alpha = \rho/\rho_c$	$\Delta H_a = \Delta H_v \alpha_3 / (\alpha_3 - \alpha_1)$
(1- γ)		$\left[\frac{\Delta H_a - (\Delta H_a)_c}{RT_c} \right]^2$
1.00000E-00		+ ∞
9.00000E-01		2.04795E+02
8.50000E-01		1.27830E+02
8.00000E-01		9.02907E+01
7.50000E-01		6.82167E+01
7.00000E-01		5.37415E+01
6.50000E-01		4.35367E+01
6.00000E-01		3.59553E+01
5.50000E-01		3.00861E+01
5.00000E-01		2.53771E+01
4.50000E-01		2.14699E+01
4.00000E-01		1.81223E+01
3.50000E-01		1.51689E+01
3.00000E-01		1.24976E+01
2.50000E-01		1.00342E+01
2.00000E-01		7.73208E-00
1.50000E-01		5.56589E-00
1.00000E-01		3.53019E-00
5.00000E-02		1.64438E-00
4.80000E-02		1.57280E-00
4.60000E-02		1.50157E-00
4.40000E-02		1.43070E-00
4.20000E-02		1.36019E-00
4.00000E-02		1.29007E-00
3.80000E-02		1.22034E-00
3.60000E-02		1.15100E-00
3.40000E-02		1.08209E-00
3.20000E-02		1.01360E-00
3.00000E-02		9.45558E-01
2.80000E-02		8.77975E-01
2.60000E-02		8.10872E-01
2.40000E-02		7.44269E-01
2.20000E-02		6.78190E-01
2.00000E-02		6.12661E-01
1.80000E-02		5.47712E-01
1.60000E-02		4.83380E-01
1.40000E-02		4.19704E-01
1.20000E-02		3.56737E-01
1.00000E-02		2.94540E-01
8.00000E-03		2.33194E-01
6.00000E-03		1.72808E-01
4.00000E-03		1.13544E-01
2.00000E-03		5.56815E-02
1.00000E-03		2.74526E-02
0.00000E-99		0.00000E-99

near the critical point, in figure 68.

FIGURE 68. - Redlich-Kwong fluid, asymptotic function of the heat of vaporization per mole of gas collected outside the calorimeter as a function of temperature.

SECOND TEMPERATURE DERIVATIVE OF THE VAPOR PRESSURE CURVE

From equations 44 and 251 of reference 3, it can be shown that

$$\beta'' = \frac{d^2\beta}{d\gamma^2} = \frac{\alpha_1 \alpha_3}{Z_c (\alpha_3 - \alpha_1)} \left[2(X_{Y(3)} - X_{Y(1)}) + \gamma(X_{YY(3)} - X_{YY(1)}) \right] + \frac{\alpha_3 [\beta' - \beta_{Y(1)}]^2}{\alpha_1 (\alpha_3 - \alpha_1) \beta_{\alpha(1)}} - \frac{\alpha_1 [\beta' - \beta_{Y(3)}]^2}{\alpha_3 (\alpha_3 - \alpha_1) \beta_{\alpha(3)}}, \quad (289)$$

which from equations 23, 37, 38, 57, 196, and 203 can be written as

$$\beta'' = \frac{(1+b\alpha_1)\alpha_3}{b(\alpha_3 - \alpha_1)\alpha_1} \beta_{YY(1)} \ln \frac{(1+b\alpha_3)}{(1+b\alpha_1)} + \frac{\alpha_3^2 (\beta' - \beta_{Y(1)}) \alpha_1' - \alpha_1^2 (\beta' - \beta_{Y(3)}) \alpha_3'}{\alpha_1 \alpha_3 (\alpha_3 - \alpha_1)}. \quad (290)$$

Values of β'' as a function of γ are listed in table 42. These data are illustrated in figures 69 and 70.

FIGURE 69. - Redlich-Kwong fluid, second temperature derivative of the vapor pressure curve as a function of temperature.

FIGURE 70. - Redlich-Kwong fluid, second temperature derivative of the vapor pressure curve as a function of temperature near the critical point.

FIGURE 68. - Redlich-Kwong Fluid, Asymptotic Function of the Heat of Vaporization Per Mole of Gas Collected Outside the Calorimeter as a Function of Temperature.

TABLE 42. - REDLICH-KWONG FLUID, SECOND TEMPERATURE DERIVATIVE OF THE VAPOR PRESSURE CURVE AS A FUNCTION OF TEMPERATURE

$\gamma = T/T_c$	$\beta = P/P_c$	$\beta'' = \frac{d^2\beta}{d\gamma^2}$
γ		β''
0.00000E-99		0.00000E-99
1.00000E-01		2.46906E-39
1.50000E-01		6.51948E-19
2.00000E-01		1.18333E-10
2.50000E-01		1.76508E-06
3.00000E-01		4.31265E-04
3.50000E-01		1.28876E-02
4.00000E-01		1.16966E-01
4.50000E-01		5.13394E-01
5.00000E-01		1.41678E+00
5.50000E-01		2.88373E+00
6.00000E-01		4.79249E+00
6.50000E-01		6.94666E+00
7.00000E-01		9.16947E+00
7.50000E-01		1.13404E+01
8.00000E-01		1.33933E+01
8.50000E-01		1.53012E+01
9.00000E-01		1.70615E+01
9.50000E-01		1.86852E+01
9.52000E-01		1.87476E+01
9.54000E-01		1.88097E+01
9.56000E-01		1.88717E+01
9.58000E-01		1.89334E+01
9.60000E-01		1.89950E+01
9.62000E-01		1.90564E+01
9.64000E-01		1.91177E+01
9.66000E-01		1.91787E+01
9.68000E-01		1.92395E+01
9.70000E-01		1.93002E+01
9.72000E-01		1.93607E+01
9.74000E-01		1.94210E+01
9.76000E-01		1.94812E+01
9.78000E-01		1.95412E+01
9.80000E-01		1.96009E+01
9.82000E-01		1.96606E+01
9.84000E-01		1.97200E+01
9.86000E-01		1.97793E+01
9.88000E-01		1.98384E+01
9.90000E-01		1.98974E+01
9.92000E-01		1.99561E+01
9.94000E-01		2.00148E+01
9.96000E-01		2.00732E+01
9.98000E-01		2.01315E+01
9.99000E-01		2.01607E+01
1.00000E-00		2.01897E+01

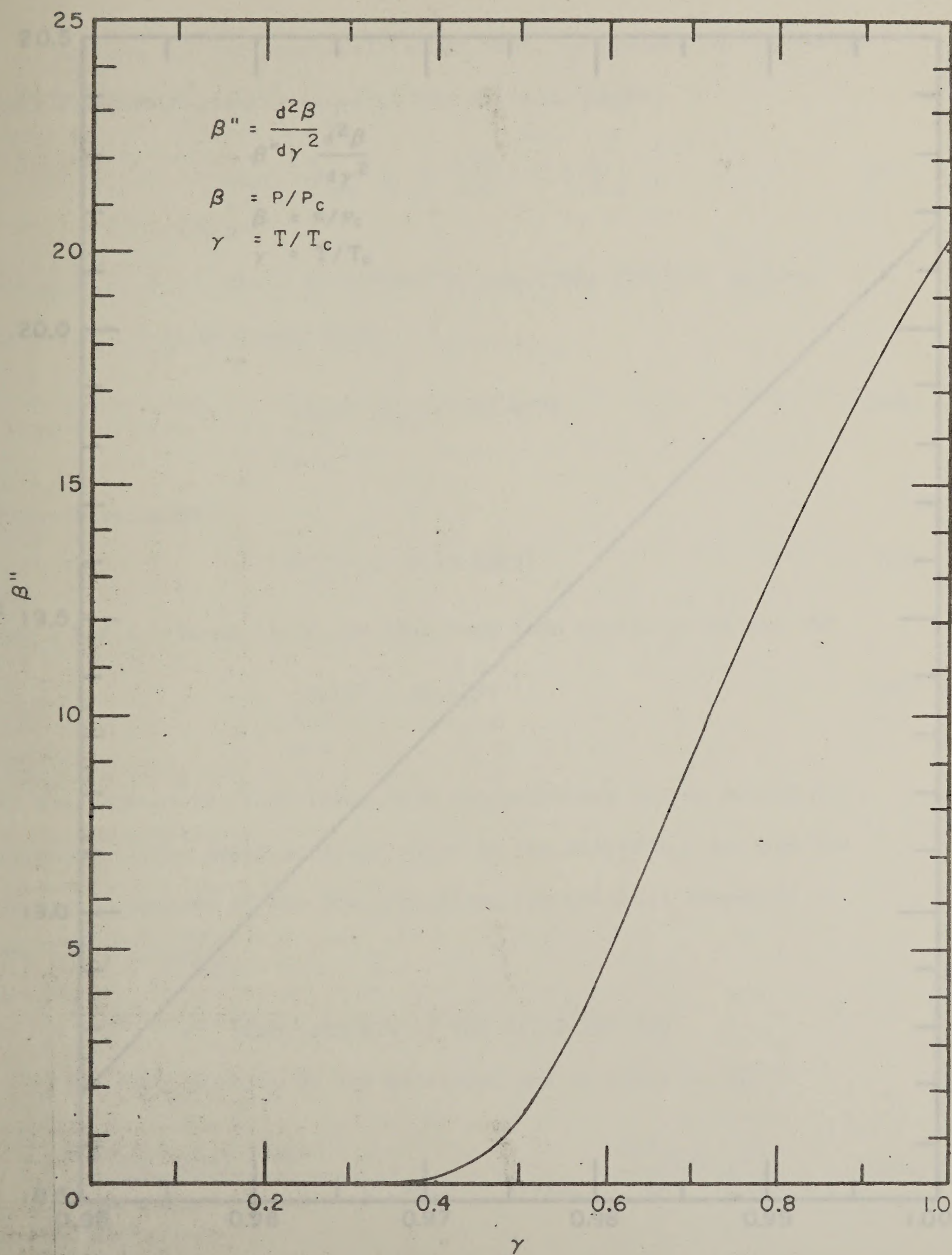


FIGURE 69.— Redlich-Kwong Fluid, Second Temperature Derivative of the Vapor Pressure Curve as a Function of Temperature.

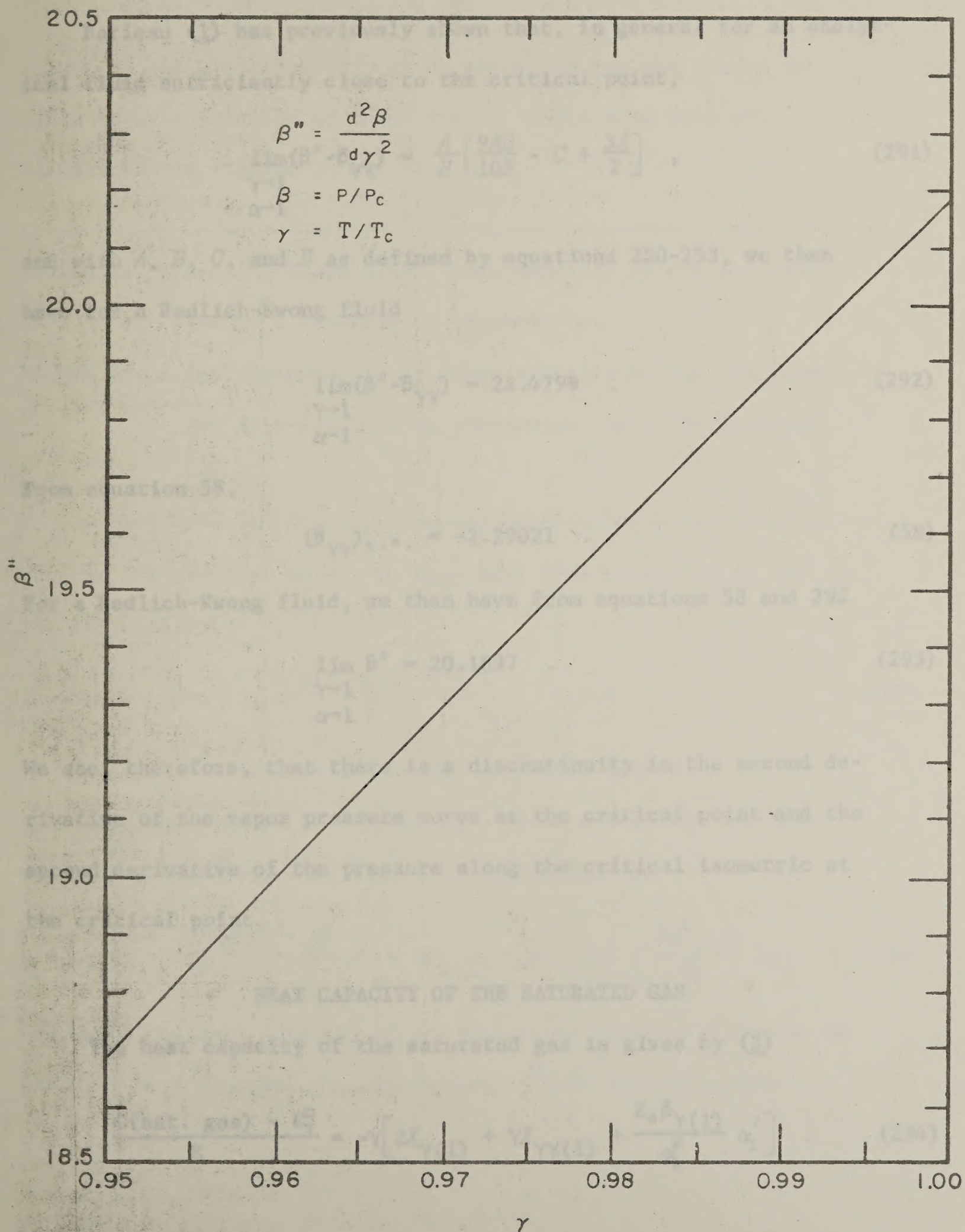


FIGURE 70.—Redlich-Kwong Fluid, Second Temperature Derivative of the Vapor Pressure Curve as a Function of Temperature Near the Critical Point.

Barieau (1) has previously shown that, in general for an analytical fluid sufficiently close to the critical point,

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha \rightarrow 1}} (\beta'' - \beta_{\gamma\gamma}) = \frac{A}{B} \left[\frac{9AD}{10B} - C + \frac{3A}{2} \right] , \quad (291)$$

and with A , B , C , and D as defined by equations 250-253, we then have for a Redlich-Kwong fluid

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha \rightarrow 1}} (\beta'' - \beta_{\gamma\gamma}) = 22.4799 . \quad (292)$$

From equation 58,

$$(\beta_{\gamma\gamma})_{c.p.} = -2.29021 . \quad (58)$$

For a Redlich-Kwong fluid, we then have from equations 58 and 292

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha \rightarrow 1}} \beta'' = 20.1897 . \quad (293)$$

We see, therefore, that there is a discontinuity in the second derivative of the vapor pressure curve at the critical point and the second derivative of the pressure along the critical isometric at the critical point.

HEAT CAPACITY OF THE SATURATED GAS

The heat capacity of the saturated gas is given by (2)

$$\frac{C(\text{sat. gas})}{R} - C_{\gamma}^0 = -\gamma \left[2X_{\gamma(1)} + \gamma X_{\gamma\gamma(1)} + \frac{Z_c \beta_{\gamma(1)}}{\alpha_1^2} \alpha_1' \right] . \quad (294)$$

Values of the heat capacity of the saturated gas are, listed in table 43 as a function of temperature. These same data are illustrated in figures 71 and 72.

FIGURE 71. - Redlich-Kwong fluid, heat capacity of the saturated gas as a function of temperature.

FIGURE 72. - Redlich-Kwong fluid, heat capacity of the saturated gas as a function of temperature near the critical point.

At the critical point, we then have from equations 23, 48, 49, 51, 211, and 294,

$$\left[\frac{C(\text{sat. gas}) - C_V^0}{R} \right]_{c.p.} = -\infty \quad (295)$$

HEAT CAPACITY OF THE SATURATED LIQUID

In a previous Bureau report (2), it is shown that the heat capacity of the saturated liquid is expressible as

$$\frac{C(\text{sat. liquid}) - C_V^0}{R} = -\gamma \left[2X_{Y(3)} + \gamma X_{YY(3)} + \frac{Z_c \beta_Y(3)}{\alpha_3^2} \alpha_3' \right] \quad (296)$$

Values of the heat capacity of the saturated liquid are listed in table 44 as a function of temperature. These same data are

TABLE 43. - REDLICH-KWONG FLUID, HEAT CAPACITY OF THE SATURATED GAS AS A FUNCTION OF TEMPERATURE

$\gamma = T/T_c$	$C(\text{sat. gas}) = T \frac{dS_1}{dT}$
γ	$\frac{C(\text{sat. gas}) - C_v^0}{R}$
0.00000E-99	- ∞
1.00000E-01	-1.60708E+02
1.50000E-01	-8.67756E+01
2.00000E-01	-5.58114E+01
2.50000E-01	-3.94779E+01
3.00000E-01	-2.96367E+01
3.50000E-01	-2.31678E+01
4.00000E-01	-1.86515E+01
4.50000E-01	-1.53753E+01
5.00000E-01	-1.29603E+01
5.50000E-01	-1.11861E+01
6.00000E-01	-9.90634E-00
6.50000E-01	-9.01625E-00
7.00000E-01	-8.44516E-00
7.50000E-01	-8.15678E-00
8.00000E-01	-8.15827E-00
8.50000E-01	-8.53243E-00
9.00000E-01	-9.56335E-00
9.50000E-01	-1.24780E+01
9.52000E-01	-1.26959E+01
9.54000E-01	-1.29290E+01
9.56000E-01	-1.31789E+01
9.58000E-01	-1.34476E+01
9.60000E-01	-1.37375E+01
9.62000E-01	-1.40513E+01
9.64000E-01	-1.43922E+01
9.66000E-01	-1.47643E+01
9.68000E-01	-1.51722E+01
9.70000E-01	-1.56221E+01
9.72000E-01	-1.61211E+01
9.74000E-01	-1.66787E+01
9.76000E-01	-1.73068E+01
9.78000E-01	-1.80211E+01
9.80000E-01	-1.88428E+01
9.82000E-01	-1.98010E+01
9.84000E-01	-2.09374E+01
9.86000E-01	-2.23135E+01
9.88000E-01	-2.40259E+01
9.90000E-01	-2.62357E+01
9.92000E-01	-2.92380E+01
9.94000E-01	-3.36499E+01
9.96000E-01	-4.10715E+01
9.98000E-01	-5.78701E+01
9.99000E-01	-8.16706E+01
1.00000E-00	- ∞

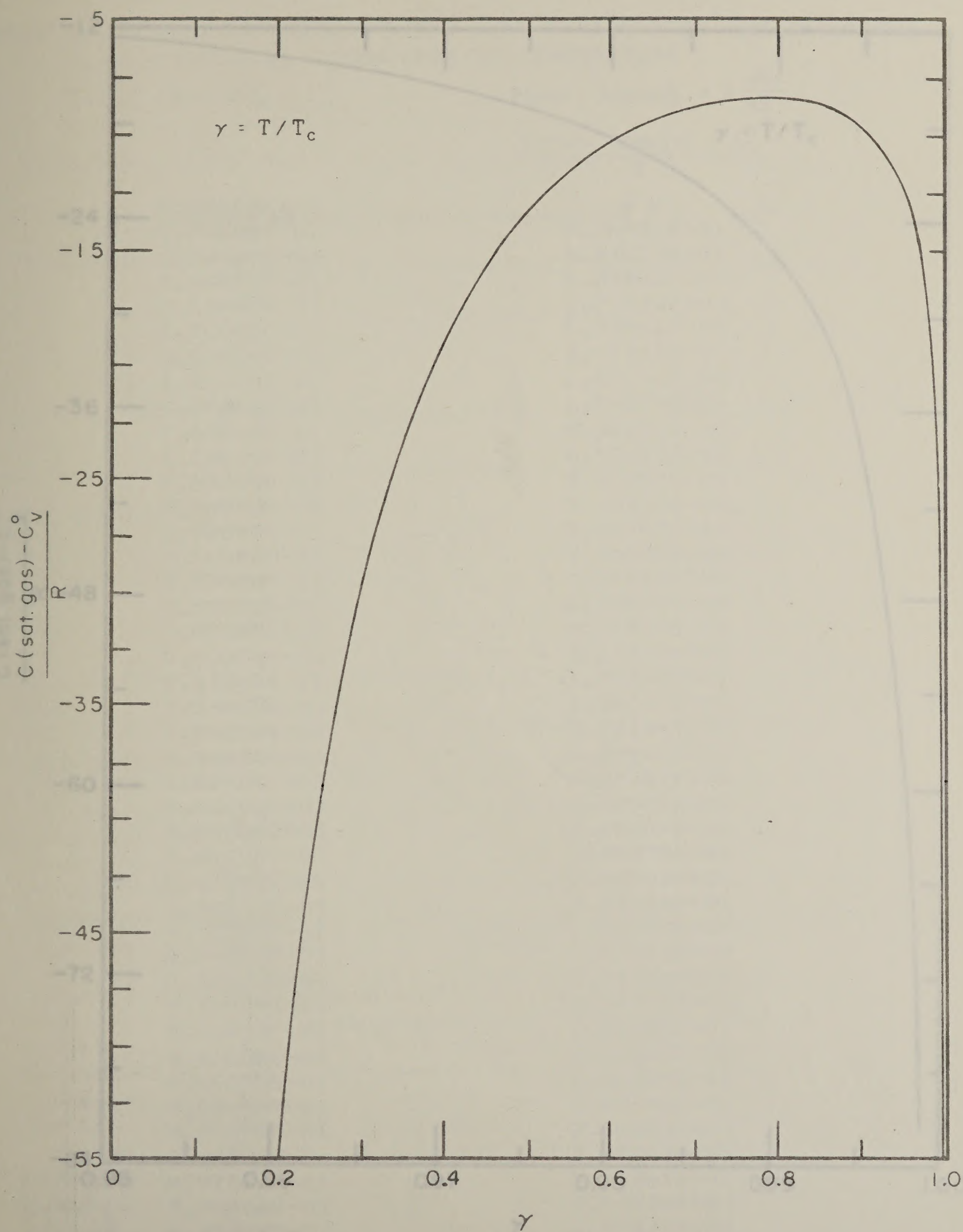


FIGURE 71.—Redlich-Kwong Fluid, Heat Capacity of the Saturated Gas as a Function of Temperature.

Near the Critical Point.

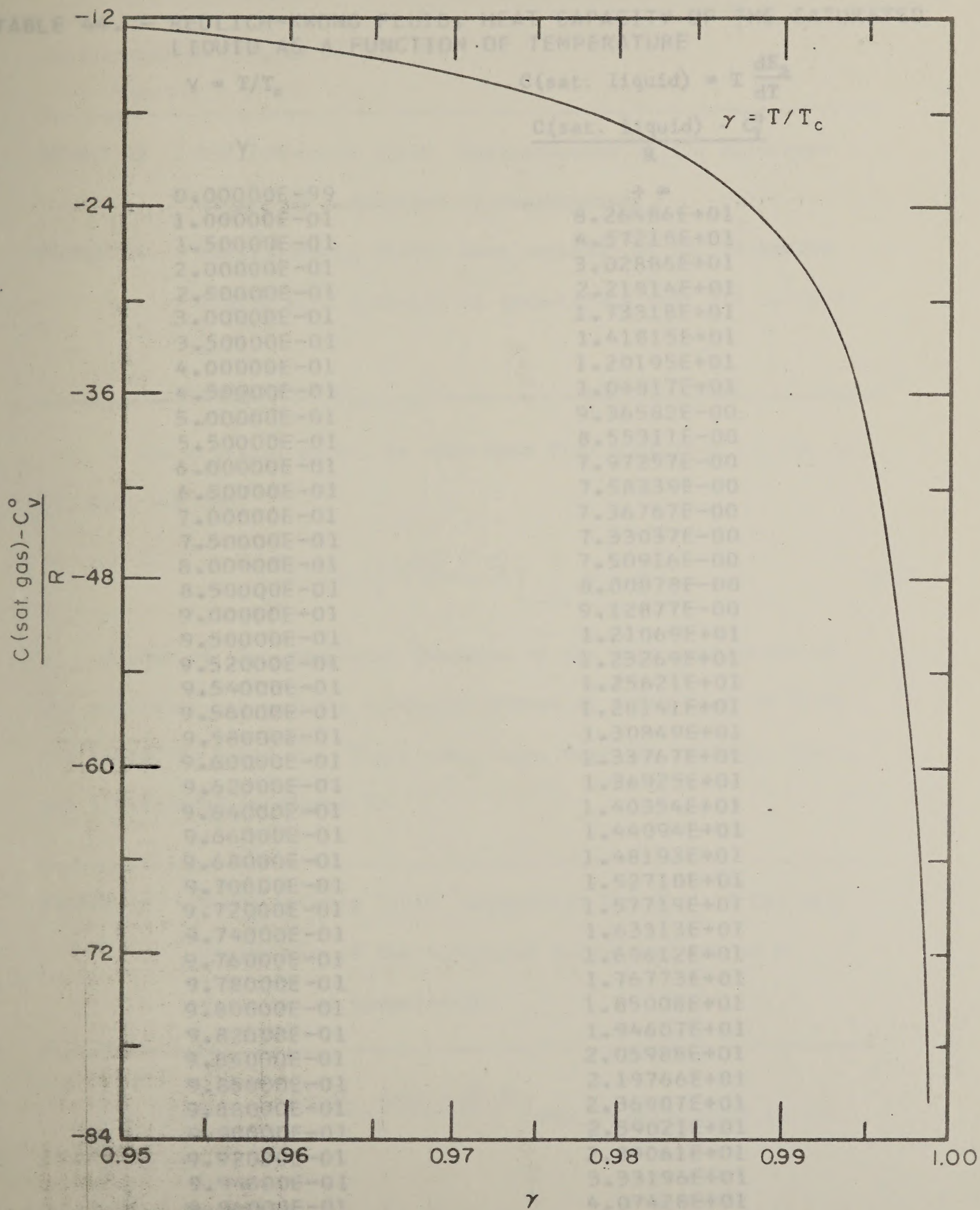


FIGURE 72. — Redlich-Kwong Fluid, Heat Capacity of the Saturated Gas as a Function of Temperature Near the Critical Point.

TABLE 44. - REDLICH-KWONG FLUID, HEAT CAPACITY OF THE SATURATED LIQUID AS A FUNCTION OF TEMPERATURE

$\gamma = T/T_c$	$C(\text{sat. liquid}) = T \frac{dS_3}{dT}$
γ	$\frac{C(\text{sat. liquid}) - C_v^0}{R}$
0.00000E-99	$+\infty$
1.00000E-01	8.26486E+01
1.50000E-01	4.57215E+01
2.00000E-01	3.02886E+01
2.50000E-01	2.21814E+01
3.00000E-01	1.73318E+01
3.50000E-01	1.41815E+01
4.00000E-01	1.20195E+01
4.50000E-01	1.04817E+01
5.00000E-01	9.36582E-00
5.50000E-01	8.55311E-00
6.00000E-01	7.97257E-00
6.50000E-01	7.58339E-00
7.00000E-01	7.36767E-00
7.50000E-01	7.33037E-00
8.00000E-01	7.50916E-00
8.50000E-01	8.00878E-00
9.00000E-01	9.12877E-00
9.50000E-01	1.21069E+01
9.52000E-01	1.23269E+01
9.54000E-01	1.25621E+01
9.56000E-01	1.28141E+01
9.58000E-01	1.30849E+01
9.60000E-01	1.33767E+01
9.62000E-01	1.36925E+01
9.64000E-01	1.40354E+01
9.66000E-01	1.44094E+01
9.68000E-01	1.48193E+01
9.70000E-01	1.52710E+01
9.72000E-01	1.57719E+01
9.74000E-01	1.63313E+01
9.76000E-01	1.69612E+01
9.78000E-01	1.76773E+01
9.80000E-01	1.85008E+01
9.82000E-01	1.94607E+01
9.84000E-01	2.05988E+01
9.86000E-01	2.19766E+01
9.88000E-01	2.36907E+01
9.90000E-01	2.59021E+01
9.92000E-01	2.89061E+01
9.94000E-01	3.33196E+01
9.96000E-01	4.07428E+01
9.98000E-01	5.75430E+01
9.99000E-01	8.13442E+01
1.00000E-00	$+\infty$

illustrated in figures 73 and 74.

FIGURE 73. - Redlich-Kwong fluid, heat capacity of the saturated liquid as a function of temperature.

FIGURE 74. - Redlich-Kwong fluid, heat capacity of the saturated liquid as a function of temperature near the critical point.

At the critical point, we then have from equations 23, 48, 49, 51, 213, and 296,

$$\left[\frac{C(\text{sat. liquid}) - C_v^0}{R} \right]_{c.p.} = +\infty \quad (297)$$

Values of the asymptotic function of the heat capacities of the saturated gas and the saturated liquid as a function of $(1-\gamma)$ are listed in table 45. These same data, near the critical point, are illustrated in figure 75.

FIGURE 75. - Redlich-Kwong fluid, asymptotic function of the heat capacities of the saturated liquid and gas as a function of temperature.

The $\lim_{\substack{\gamma \rightarrow 1 \\ \alpha_1 \rightarrow 1}} \left[(1-\gamma) \left(\frac{C(\text{sat. gas}) - C_v^0}{R} \right)^2 \right]$ may be determined in the

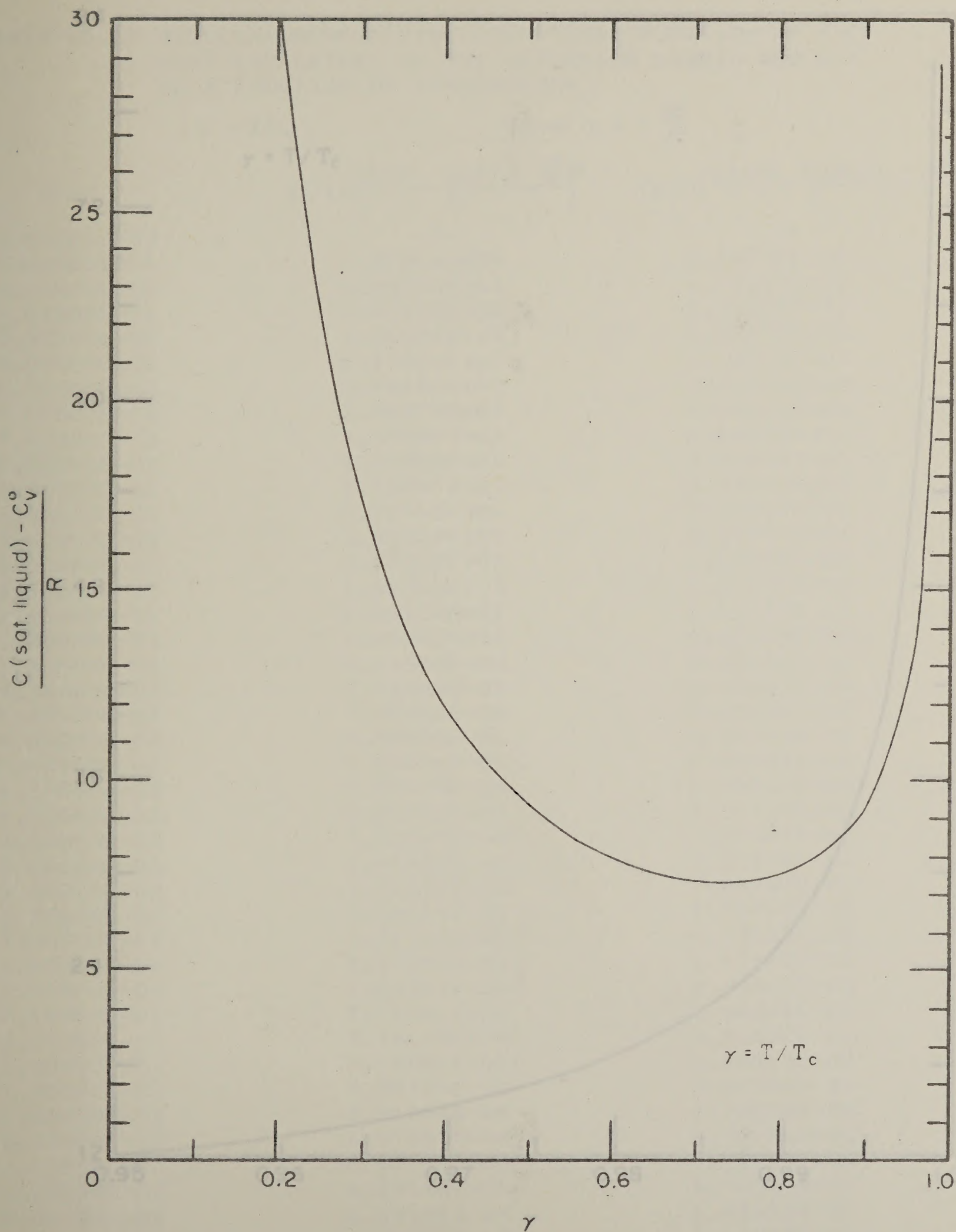


FIGURE 73.— Redlich-Kwong Fluid, Heat Capacity of the Saturated Liquid as a Function of Temperature.

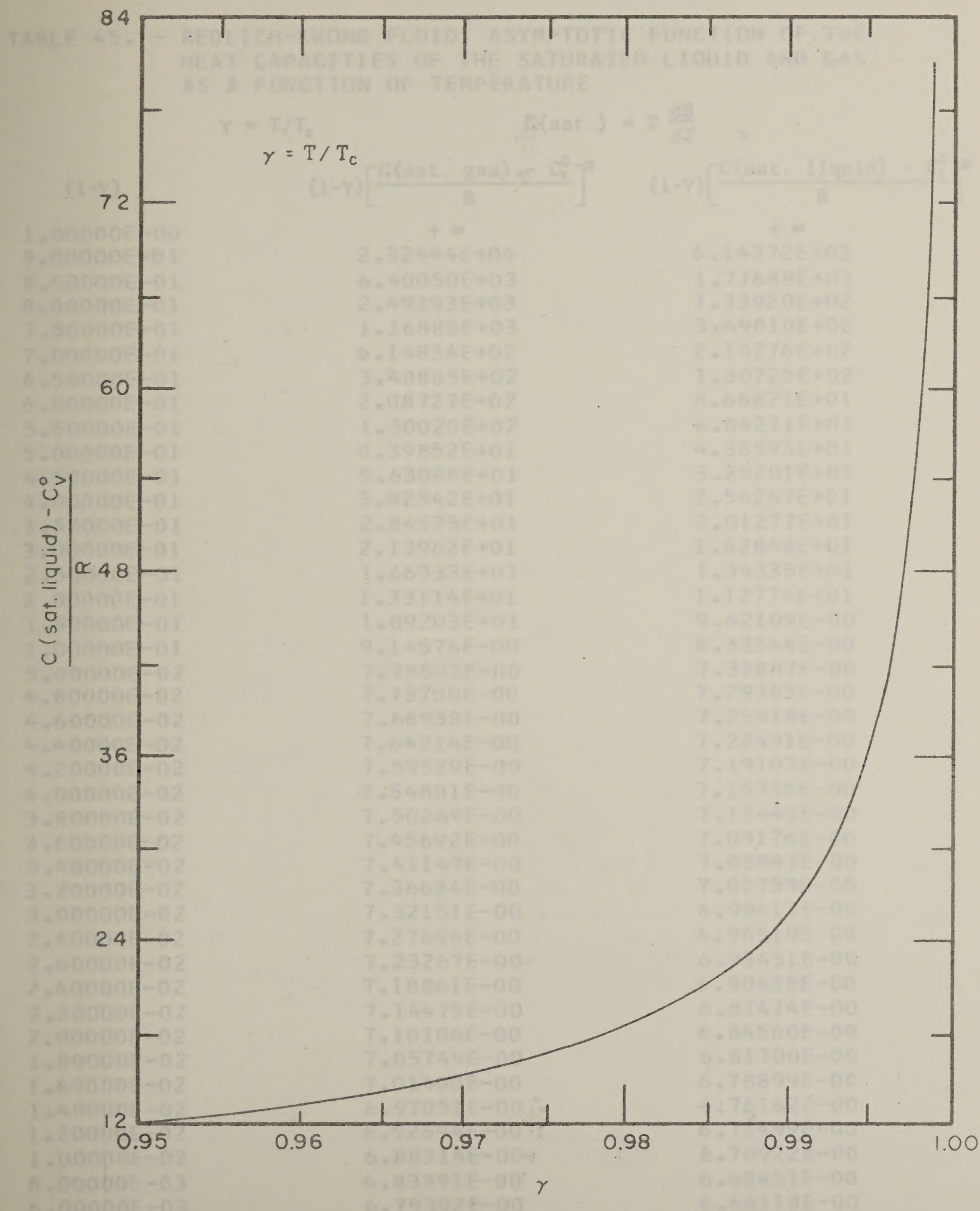


FIGURE 74. - Redlich-Kwong Fluid, Heat Capacity of the Saturated Liquid as a Function of Temperature Near the Critical Point.

TABLE 45. - REDLICH-KWONG FLUID, ASYMPTOTIC FUNCTION OF THE HEAT CAPACITIES OF THE SATURATED LIQUID AND GAS AS A FUNCTION OF TEMPERATURE

$$\gamma = T/T_c$$

$$C(\text{sat.}) = T \frac{dS}{dT}$$

(1- γ)	(1- γ) $\left[\frac{C(\text{sat. gas}) - C_v^0}{R} \right]^2$	(1- γ) $\left[\frac{C(\text{sat. liquid}) - C_v^0}{R} \right]^2$
1.00000E-00	+ ∞	+ ∞
9.00000E-01	2.32444E+04	6.14772E+03
8.50000E-01	6.40050E+03	1.77689E+03
8.00000E-01	2.49193E+03	7.33920E+02
7.50000E-01	1.16888E+03	3.69010E+02
7.00000E-01	6.14834E+02	2.10276E+02
6.50000E-01	3.48885E+02	1.30725E+02
6.00000E-01	2.08727E+02	8.66821E+01
5.50000E-01	1.30020E+02	6.04271E+01
5.00000E-01	8.39852E+01	4.38593E+01
4.50000E-01	5.63088E+01	3.29201E+01
4.00000E-01	3.92542E+01	2.54247E+01
3.50000E-01	2.84525E+01	2.01277E+01
3.00000E-01	2.13962E+01	1.62848E+01
2.50000E-01	1.66333E+01	1.34335E+01
2.00000E-01	1.33114E+01	1.12774E+01
1.50000E-01	1.09203E+01	9.62109E-00
1.00000E-01	9.14576E-00	8.33344E-00
5.00000E-02	7.78503E-00	7.32887E-00
4.80000E-02	7.73700E-00	7.29383E-00
4.60000E-02	7.68938E-00	7.25918E-00
4.40000E-02	7.64214E-00	7.22491E-00
4.20000E-02	7.59529E-00	7.19103E-00
4.00000E-02	7.54881E-00	7.15755E-00
3.80000E-02	7.50269E-00	7.12445E-00
3.60000E-02	7.45692E-00	7.09176E-00
3.40000E-02	7.41147E-00	7.05947E-00
3.20000E-02	7.36634E-00	7.02759E-00
3.00000E-02	7.32151E-00	6.99613E-00
2.80000E-02	7.27696E-00	6.96510E-00
2.60000E-02	7.23267E-00	6.93451E-00
2.40000E-02	7.18861E-00	6.90438E-00
2.20000E-02	7.14475E-00	6.87474E-00
2.00000E-02	7.10106E-00	6.84560E-00
1.80000E-02	7.05749E-00	6.81700E-00
1.60000E-02	7.01400E-00	6.78899E-00
1.40000E-02	6.97051E-00	6.76162E-00
1.20000E-02	6.92694E-00	6.73499E-00
1.00000E-02	6.88314E-00	6.70922E-00
8.00000E-03	6.83891E-00	6.68451E-00
6.00000E-03	6.79392E-00	6.66118E-00
4.00000E-03	6.74749E-00	6.63991E-00
2.00000E-03	6.69791E-00	6.62239E-00
1.00000E-03	6.67010E-00	6.61688E-00
0.00000E-99	6.62690E-00	6.62690E-00

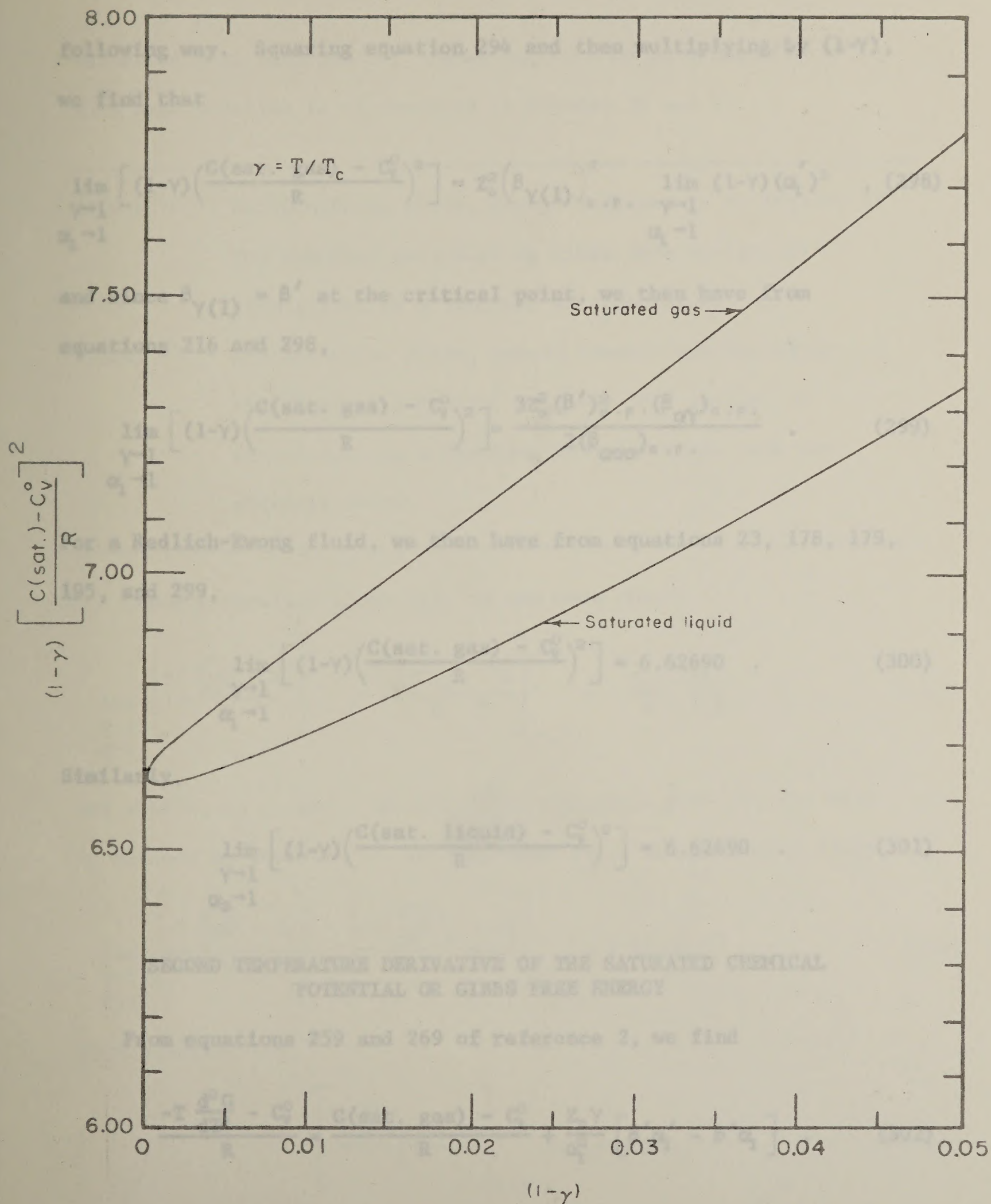


FIGURE 75.-Redlich-Kwong Fluid, Asymptotic Function of the Heat Capacities of the Saturated Liquid and Gas as a Function of Temperature.

following way. Squaring equation 294 and then multiplying by $(1-\gamma)$, we find that

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha_1 \rightarrow 1}} \left[(1-\gamma) \left(\frac{C(\text{sat. gas}) - C_v^0}{R} \right)^2 \right] = Z_c^2 \left(\beta_{\gamma(1)} \right)_{c.p.}^2 \lim_{\substack{\gamma \rightarrow 1 \\ \alpha_1 \rightarrow 1}} (1-\gamma) (\alpha_1')^2, \quad (298)$$

and since $\beta_{\gamma(1)} = \beta'$ at the critical point, we then have from equations 216 and 298,

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha_1 \rightarrow 1}} \left[(1-\gamma) \left(\frac{C(\text{sat. gas}) - C_v^0}{R} \right)^2 \right] = \frac{3Z_c^2 (\beta')_{c.p.}^2 (\beta_{\alpha\gamma})_{c.p.}}{2(\beta_{\alpha\alpha\alpha})_{c.p.}}. \quad (299)$$

For a Redlich-Kwong fluid, we then have from equations 23, 178, 179, 195, and 299,

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha_1 \rightarrow 1}} \left[(1-\gamma) \left(\frac{C(\text{sat. gas}) - C_v^0}{R} \right)^2 \right] = 6.62690. \quad (300)$$

Similarly,

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha_3 \rightarrow 1}} \left[(1-\gamma) \left(\frac{C(\text{sat. liquid}) - C_v^0}{R} \right)^2 \right] = 6.62690. \quad (301)$$

SECOND TEMPERATURE DERIVATIVE OF THE SATURATED CHEMICAL POTENTIAL OR GIBBS FREE ENERGY

From equations 259 and 269 of reference 2, we find

$$\frac{-T \frac{d^2 G}{dT^2} - C_v^0}{R} = \frac{C(\text{sat. gas}) - C_v^0}{R} + \frac{Z_c \gamma}{\alpha_1^2} \left[\beta' \alpha_1' - \beta'' \alpha_1 \right]. \quad (302)$$

Values of this function are listed in table 46 as a function of γ .

This same function is illustrated in figures 76 and 77.

FIGURE 76. - Redlich-Kwong fluid, second temperature derivative of the chemical potential or Gibbs free energy, at saturation, as a function of temperature.

FIGURE 77. - Redlich-Kwong fluid, second temperature derivative of the chemical potential or Gibbs free energy, at saturation, as a function of temperature near the critical point.

From a previous paper (1), we can show that

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha \rightarrow 1}} \left[\frac{-T \frac{d^2 G}{dT^2} - C_v^0}{R} \right] - \left[\frac{-T \left(\frac{\partial^2 G}{\partial T^2} \right)_\rho - C_v^0}{R} \right]_{c.p.} = - \frac{Z_c A}{B} \left[\frac{9AD}{10B} - C \right], \quad (303)$$

and with A , B , C , and D as defined by equations 250-253, and with Z_c defined by equation 23, we then have for a Redlich-Kwong fluid,

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha \rightarrow 1}} \left[\frac{-T \frac{d^2 G}{dT^2} - C_v^0}{R} \right] - \left[\frac{-T \left(\frac{\partial^2 G}{\partial T^2} \right)_\rho - C_v^0}{R} \right]_{c.p.} = 2.99686. \quad (304)$$

From equation 110,

$$\left[\frac{-T \left(\frac{\partial^2 G}{\partial T^2} \right)_\rho - C_v^0}{R} \right]_{c.p.} = 1.61839. \quad (305)$$

TABLE 46. - REDLICH-KWONG FLUID, SECOND TEMPERATURE DERIVATIVE OF THE CHEMICAL POTENTIAL OR GIBBS FREE ENERGY, AT SATURATION, AS A FUNCTION OF TEMPERATURE

$\gamma = T/T_c$	$\frac{-T \frac{d^2 G}{dT^2} - C_v^0}{R}$
0.00000E-99	+ ∞
1.00000E-01	8.26486E+01
1.50000E-01	4.57215E+01
2.00000E-01	3.02886E+01
2.50000E-01	2.21814E+01
3.00000E-01	1.73318E+01
3.50000E-01	1.41811E+01
4.00000E-01	1.20149E+01
4.50000E-01	1.04583E+01
5.00000E-01	9.29106E-00
5.50000E-01	8.37786E-00
6.00000E-01	7.63678E-00
6.50000E-01	7.01943E-00
7.00000E-01	6.49687E-00
7.50000E-01	6.05069E-00
8.00000E-01	5.66824E-00
8.50000E-01	5.34013E-00
9.00000E-01	5.05902E-00
9.50000E-01	4.81900E-00
9.52000E-01	4.81019E-00
9.54000E-01	4.80143E-00
9.56000E-01	4.79273E-00
9.58000E-01	4.78408E-00
9.60000E-01	4.77549E-00
9.62000E-01	4.76696E-00
9.64000E-01	4.75849E-00
9.66000E-01	4.75007E-00
9.68000E-01	4.74170E-00
9.70000E-01	4.73340E-00
9.72000E-01	4.72514E-00
9.74000E-01	4.71694E-00
9.76000E-01	4.70880E-00
9.78000E-01	4.70071E-00
9.80000E-01	4.69268E-00
9.82000E-01	4.68470E-00
9.84000E-01	4.67677E-00
9.86000E-01	4.66890E-00
9.88000E-01	4.66108E-00
9.90000E-01	4.65331E-00
9.92000E-01	4.64560E-00
9.94000E-01	4.63794E-00
9.96000E-01	4.63033E-00
9.98000E-01	4.62277E-00
9.99000E-01	4.61899E-00
1.00000E-00	4.61526E-00

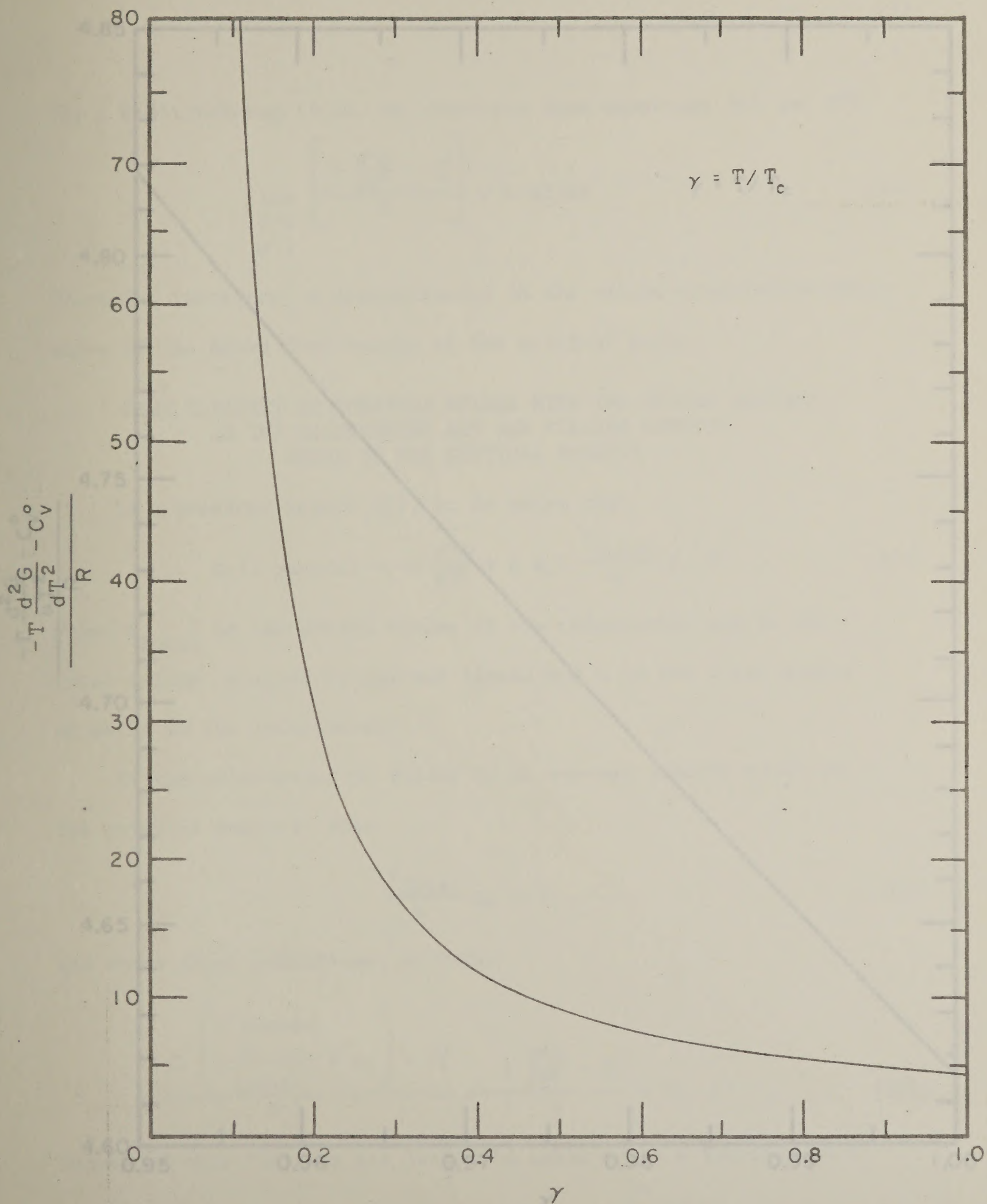


FIGURE 76. — Redlich-Kwong Fluid, Second Temperature Derivative of the Chemical Potential or Gibbs Free Energy, at Saturation, as a Function of Temperature.

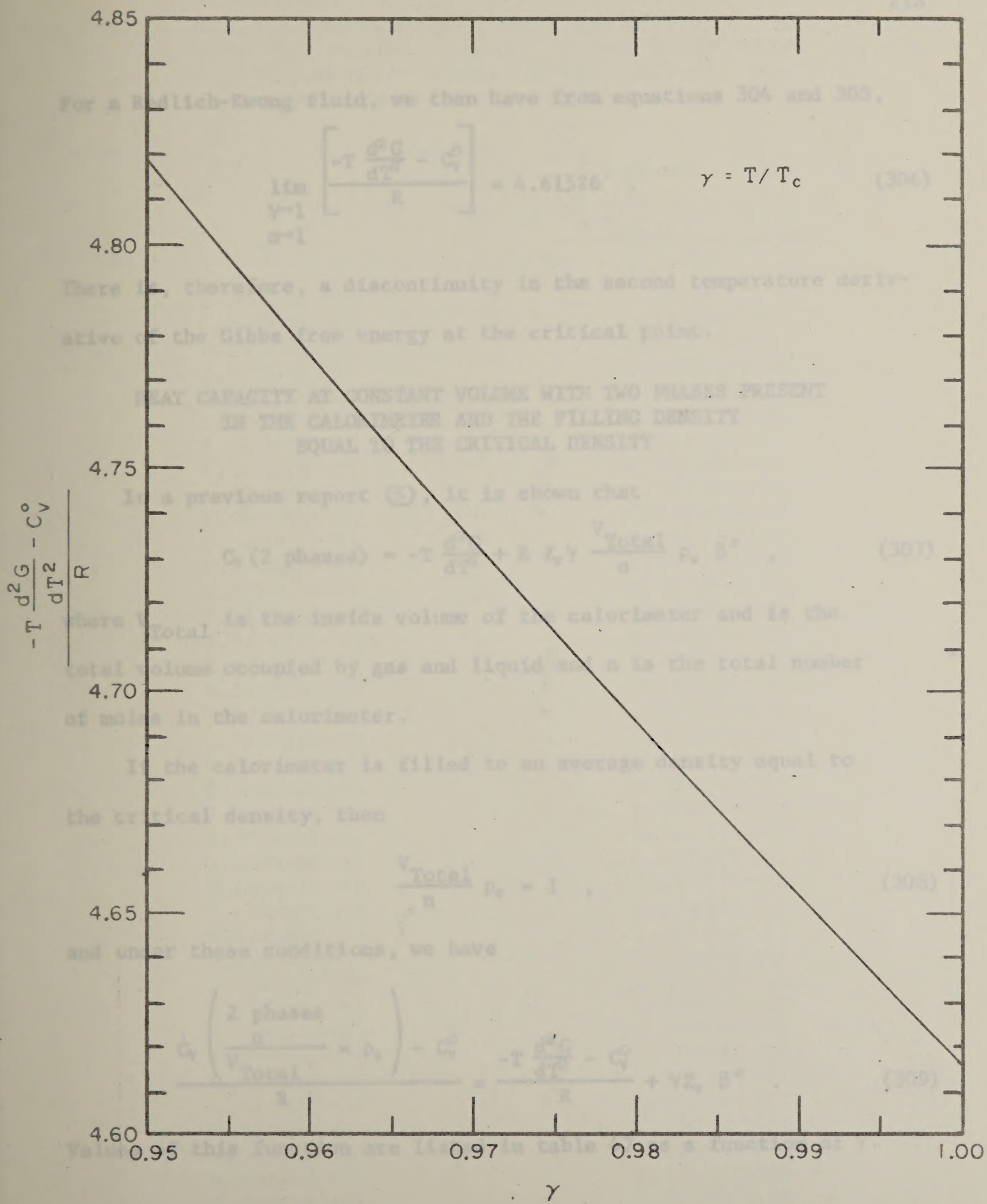


FIGURE 77. - Redlich-Kwong Fluid, Second Temperature Derivative of the Chemical Potential or Gibbs Free Energy, at Saturation, as a Function of Temperature Near the Critical Point.

For a Redlich-Kwong fluid, we then have from equations 304 and 305,

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha \rightarrow 1}} \left[\frac{-T \frac{d^2 G}{dT^2} - C_v^0}{R} \right] = 4.61526 \quad (306)$$

There is, therefore, a discontinuity in the second temperature derivative of the Gibbs free energy at the critical point.

HEAT CAPACITY AT CONSTANT VOLUME WITH TWO PHASES PRESENT IN THE CALORIMETER AND THE FILLING DENSITY EQUAL TO THE CRITICAL DENSITY

In a previous report (5), it is shown that

$$C_v (2 \text{ phases}) = -T \frac{d^2 G}{dT^2} + R Z_c \gamma \frac{V_{\text{Total}}}{n} \rho_c \beta'' \quad (307)$$

where V_{Total} is the inside volume of the calorimeter and is the total volume occupied by gas and liquid and n is the total number of moles in the calorimeter.

If the calorimeter is filled to an average density equal to the critical density, then

$$\frac{V_{\text{Total}}}{n} \rho_c = 1 \quad (308)$$

and under these conditions, we have

$$\frac{C_v \left(\frac{n}{V_{\text{Total}}} = \rho_c \right) - C_v^0}{R} = \frac{-T \frac{d^2 G}{dT^2} - C_v^0}{R} + \gamma Z_c \beta'' \quad (309)$$

Values of this function are listed in table 47 as a function of γ .

TABLE 47. - REDLICH-KWONG FLUID, HEAT CAPACITY AT CONSTANT VOLUME, WITH TWO PHASES PRESENT IN THE CALORIMETER AND THE FILLING DENSITY EQUAL TO THE CRITICAL DENSITY, AS A FUNCTION OF TEMPERATURE

$\gamma = T/T_c$	$C_v \left(\frac{2 \text{ phases}}{\frac{n}{V_{\text{Total}}} = \rho_c} \right) - C_v^0$
γ	R
0.00000E-99	+ ∞
1.00000E-01	8.26486E+01
1.50000E-01	4.57215E+01
2.00000E-01	3.02886E+01
2.50000E-01	2.21814E+01
3.00000E-01	1.73319E+01
3.50000E-01	1.41826E+01
4.00000E-01	1.20305E+01
4.50000E-01	1.05353E+01
5.00000E-01	9.52719E-00
5.50000E-01	8.90654E-00
6.00000E-01	8.59528E-00
6.50000E-01	8.52455E-00
7.00000E-01	8.63641E-00
7.50000E-01	8.88580E-00
8.00000E-01	9.23980E-00
8.50000E-01	9.67548E-00
9.00000E-01	1.01775E+01
9.50000E-01	1.07360E+01
9.52000E-01	1.07594E+01
9.54000E-01	1.07829E+01
9.56000E-01	1.08065E+01
9.58000E-01	1.08301E+01
9.60000E-01	1.08539E+01
9.62000E-01	1.08777E+01
9.64000E-01	1.09016E+01
9.66000E-01	1.09256E+01
9.68000E-01	1.09496E+01
9.70000E-01	1.09738E+01
9.72000E-01	1.09980E+01
9.74000E-01	1.10223E+01
9.76000E-01	1.10466E+01
9.78000E-01	1.10711E+01
9.80000E-01	1.10956E+01
9.82000E-01	1.11202E+01
9.84000E-01	1.11449E+01
9.86000E-01	1.11697E+01
9.88000E-01	1.11945E+01
9.90000E-01	1.12194E+01
9.92000E-01	1.12444E+01
9.94000E-01	1.12695E+01
9.96000E-01	1.12946E+01
9.98000E-01	1.13198E+01
9.99000E-01	1.13325E+01
1.00000E-00	1.13451E+01

This same function is illustrated in figures 78 and 79.

FIGURE 78. - Redlich-Kwong fluid, heat capacity at constant volume, with two phases present in the calorimeter and the filling density equal to the critical density, as a function of temperature.

FIGURE 79. - Redlich-Kwong fluid, heat capacity at constant volume, with two phases present in the calorimeter and the filling density equal to the critical density, as a function of temperature near the critical point.

From equations 23, 293, 306, and 309, it follows that

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha \rightarrow 1}} \left[\frac{C_V \left(\frac{2 \text{ phases}}{V_{\text{Total}}} = \rho_c \right) - C_V^0}{R} \right] = 11.3451 \quad (310)$$

SATURATED PRESSURE-TEMPERATURE COEFFICIENTS AT CONSTANT DENSITY

From equation 50,

$$\beta_{\gamma(1)} = \left(\frac{\partial \beta}{\partial \gamma} \right)_{\alpha_1} = 3\alpha_1 \left[\frac{1}{(1-b\alpha_1)} + \frac{a\alpha_1}{2\gamma^{3/2}(1+b\alpha_1)} \right] ; \quad (311)$$

FIGURE 78. - Redlich-Kwong Fluid, Heat Capacity at Constant Volume, With Two Phases Present in the Calorimeter and the Filling Density Equal to the Critical Density, as a Function of Temperature.

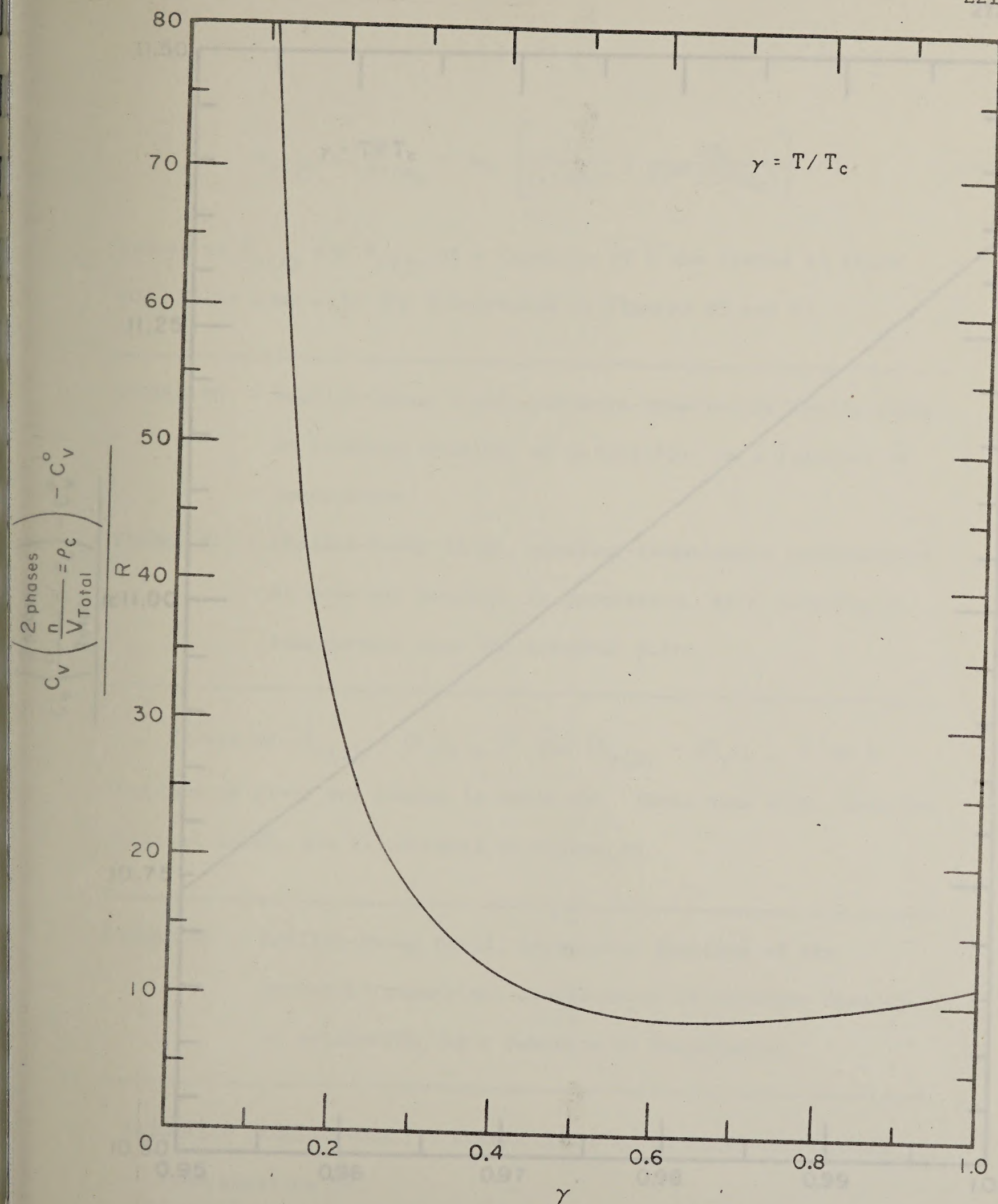


FIGURE 78. — Redlich-Kwong Fluid, Heat Capacity at Constant Volume, With Two Phases Present in the Calorimeter and the Filling Density Equal to the Critical Density, as a Function of Temperature.

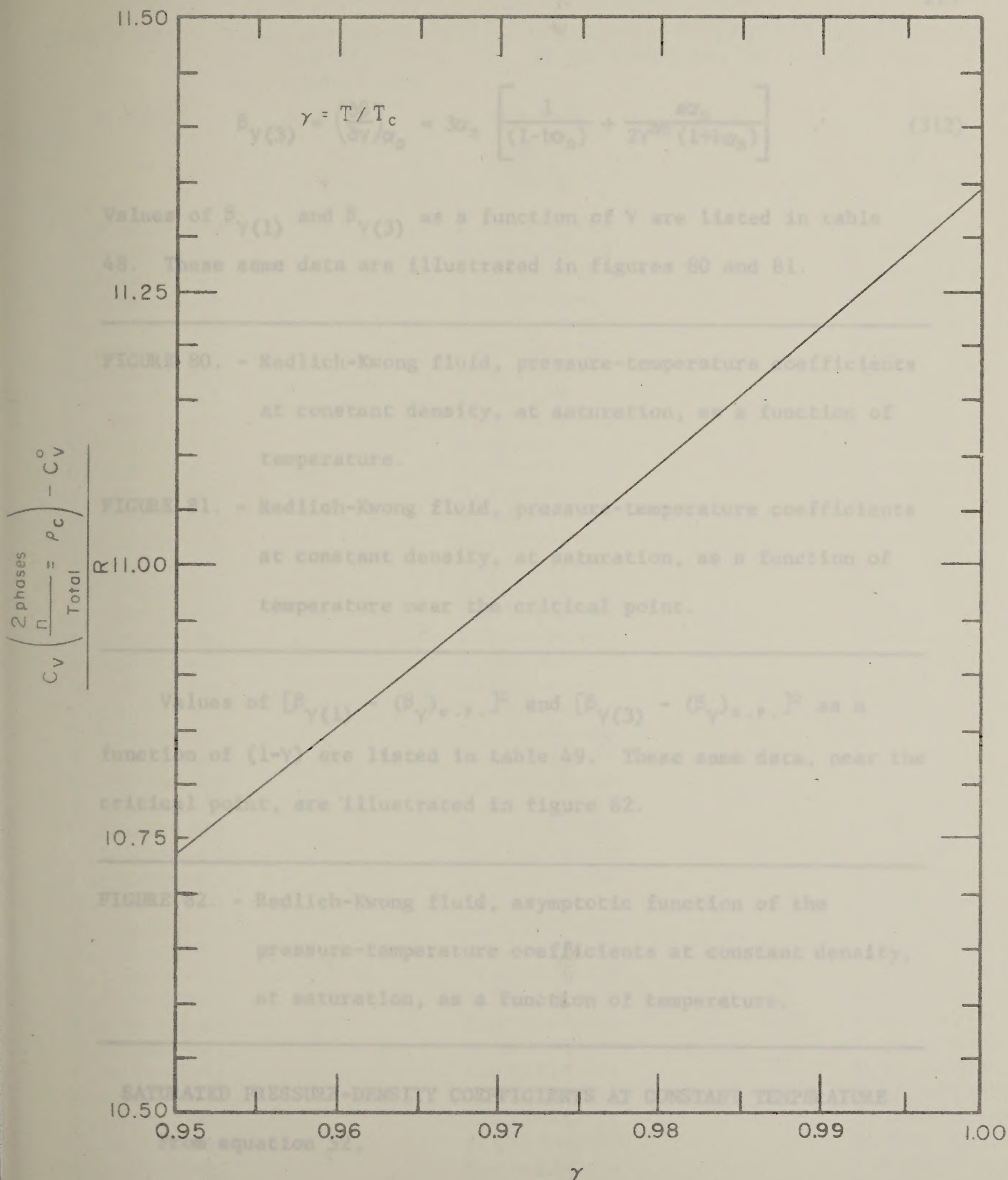


FIGURE 79.-Redlich-Kwong Fluid, Heat Capacity at Constant Volume, With Two Phases Present in the Calorimeter and the Filling Density Equal to the Critical Density, as a Function of Temperature Near the Critical Point.

$$\beta_{Y(3)} = \left(\frac{\partial \beta}{\partial Y} \right)_{\alpha_3} = 3\alpha_3 \left[\frac{1}{(1-b\alpha_3)} + \frac{a\alpha_3}{2Y^{3/2}(1+b\alpha_3)} \right] \quad (312)$$

Values of $\beta_{Y(1)}$ and $\beta_{Y(3)}$ as a function of Y are listed in table 48. These same data are illustrated in figures 80 and 81.

FIGURE 80. - Redlich-Kwong fluid, pressure-temperature coefficients at constant density, at saturation, as a function of temperature.

FIGURE 81. - Redlich-Kwong fluid, pressure-temperature coefficients at constant density, at saturation, as a function of temperature near the critical point.

Values of $[\beta_{Y(1)} - (\beta_Y)_{c.p.}]^2$ and $[\beta_{Y(3)} - (\beta_Y)_{c.p.}]^2$ as a function of $(1-Y)$ are listed in table 49. These same data, near the critical point, are illustrated in figure 82.

FIGURE 82. - Redlich-Kwong fluid, asymptotic function of the pressure-temperature coefficients at constant density, at saturation, as a function of temperature.

SATURATED PRESSURE-DENSITY COEFFICIENTS AT CONSTANT TEMPERATURE

From equation 52,

TABLE 48. - REDLICH-KWONG FLUID, PRESSURE-TEMPERATURE COEFFICIENTS
AT CONSTANT DENSITY, AT SATURATION, AS A FUNCTION
OF TEMPERATURE

$\gamma = T/T_c$	$\alpha = \rho/\rho_c$	$\beta = P/P_c$
γ	$\left(\frac{\partial \beta}{\partial \gamma}\right)_{\alpha_1}$	$\left(\frac{\partial \beta}{\partial \gamma}\right)_{\alpha_3}$
0.00000E-99	0.00000E-99	+ ∞
1.00000E-01	9.59064E-45	1.32454E+03
1.50000E-01	1.30663E-23	7.09009E+02
2.00000E-01	7.67249E-15	4.51218E+02
2.50000E-01	2.87224E-10	3.15240E+02
3.00000E-01	1.50266E-07	2.33317E+02
3.50000E-01	8.63232E-06	1.79464E+02
4.00000E-01	1.39419E-04	1.41802E+02
4.50000E-01	1.02787E-03	1.14207E+02
5.00000E-01	4.55405E-03	9.32338E+01
5.50000E-01	1.43477E-02	7.68124E+01
6.00000E-01	3.58279E-02	6.36316E+01
6.50000E-01	7.62239E-02	5.28235E+01
7.00000E-01	1.45158E-01	4.37907E+01
7.50000E-01	2.56260E-01	3.61059E+01
8.00000E-01	4.30677E-01	2.94487E+01
8.50000E-01	7.05159E-01	2.35613E+01
9.00000E-01	1.15467E-00	1.82017E+01
9.50000E-01	1.98400E-00	1.30372E+01
9.52000E-01	2.03254E-00	1.28257E+01
9.54000E-01	2.08294E-00	1.26131E+01
9.56000E-01	2.13534E-00	1.23993E+01
9.58000E-01	2.18989E-00	1.21840E+01
9.60000E-01	2.24676E-00	1.19672E+01
9.62000E-01	2.30613E-00	1.17486E+01
9.64000E-01	2.36821E-00	1.15280E+01
9.66000E-01	2.43327E-00	1.13051E+01
9.68000E-01	2.50157E-00	1.10797E+01
9.70000E-01	2.57346E-00	1.08514E+01
9.72000E-01	2.64930E-00	1.06199E+01
9.74000E-01	2.72958E-00	1.03847E+01
9.76000E-01	2.81483E-00	1.01451E+01
9.78000E-01	2.90572E-00	9.90069E-00
9.80000E-01	3.00308E-00	9.65041E-00
9.82000E-01	3.10797E-00	9.39329E-00
9.84000E-01	3.22171E-00	9.12798E-00
9.86000E-01	3.34611E-00	8.85269E-00
9.88000E-01	3.48364E-00	8.56493E-00
9.90000E-01	3.63785E-00	8.26115E-00
9.92000E-01	3.81423E-00	7.93585E-00
9.94000E-01	4.02205E-00	7.57976E-00
9.96000E-01	4.27942E-00	7.17476E-00
9.98000E-01	4.63329E-00	6.67391E-00
9.99000E-01	4.89669E-00	6.33726E-00
1.00000E-00	5.58043E-00	5.58043E-00

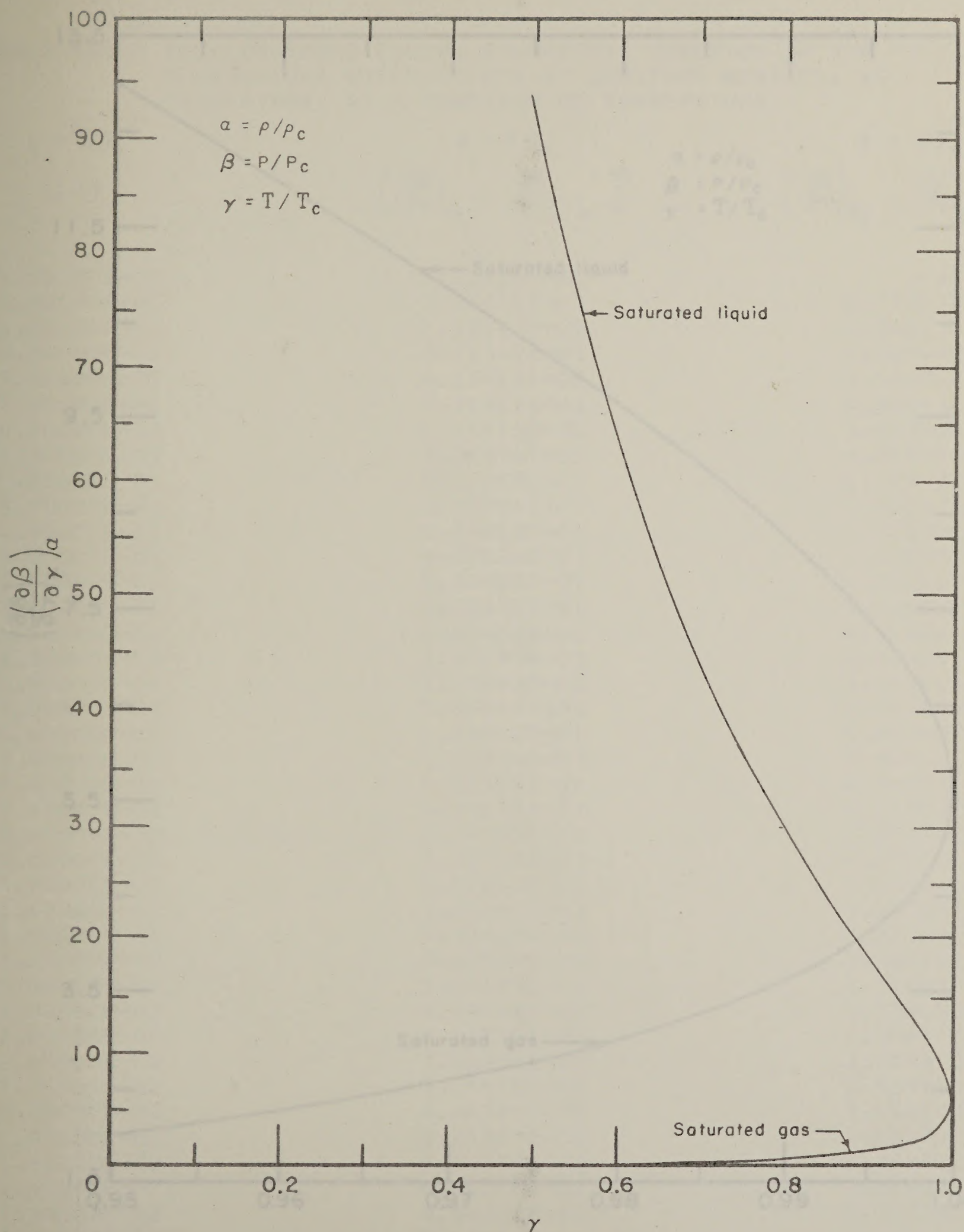


FIGURE 80. - Redlich-Kwong Fluid, Pressure - Temperature Coefficients at Constant Density, at Saturation, as a Function of Temperature.

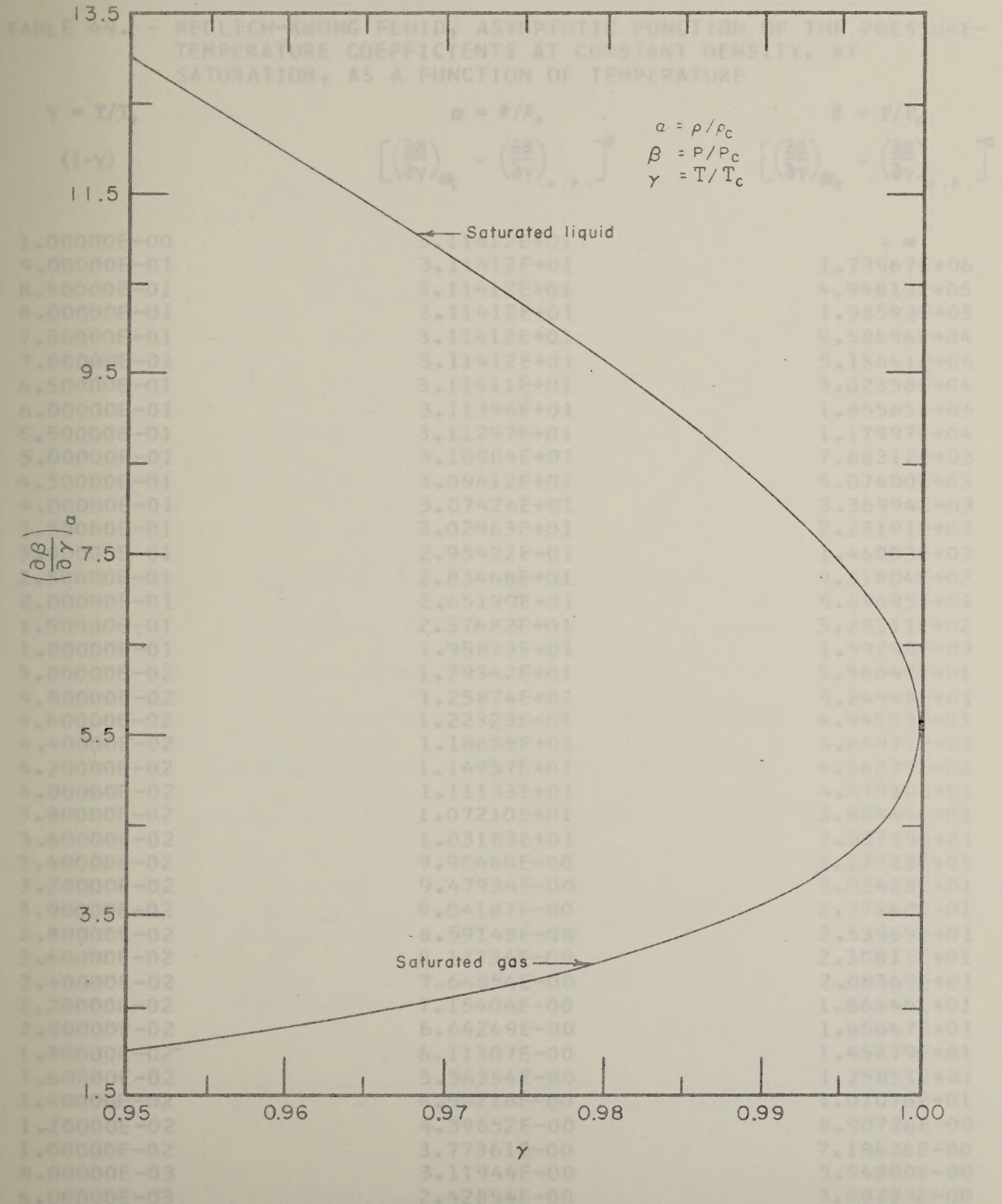


FIGURE 81. - Redlich - Kwong Fluid, Pressure-Temperature Coefficients at Constant Density, at Saturation, as a Function of Temperature Near the Critical Point.

TABLE 49. - REDLICH-KWONG FLUID, ASYMPTOTIC FUNCTION OF THE PRESSURE-TEMPERATURE COEFFICIENTS AT CONSTANT DENSITY, AT SATURATION, AS A FUNCTION OF TEMPERATURE

$\gamma = T/T_c$ (1- γ)	$\alpha = p/p_c$ $\left[\left(\frac{\partial \beta}{\partial \gamma} \right)_{\alpha_1} - \left(\frac{\partial \beta}{\partial \gamma} \right)_{c.p.} \right]^2$	$\beta = P/P_c$ $\left[\left(\frac{\partial \beta}{\partial \gamma} \right)_{\alpha_3} - \left(\frac{\partial \beta}{\partial \gamma} \right)_{c.p.} \right]^2$
1.00000E-00	3.11412E+01	+ ∞
9.00000E-01	3.11412E+01	1.73967E+06
8.50000E-01	3.11412E+01	4.94813E+05
8.00000E-01	3.11412E+01	1.98593E+05
7.50000E-01	3.11412E+01	9.58896E+04
7.00000E-01	3.11412E+01	5.18641E+04
6.50000E-01	3.11411E+01	3.02358E+04
6.00000E-01	3.11396E+01	1.85565E+04
5.50000E-01	3.11297E+01	1.17997E+04
5.00000E-01	3.10904E+01	7.68312E+03
4.50000E-01	3.09812E+01	5.07400E+03
4.00000E-01	3.07426E+01	3.36994E+03
3.50000E-01	3.02963E+01	2.23191E+03
3.00000E-01	2.95422E+01	1.46003E+03
2.50000E-01	2.83468E+01	9.31804E+02
2.00000E-01	2.65199E+01	5.69695E+02
1.50000E-01	2.37682E+01	3.23311E+02
1.00000E-01	1.95873E+01	1.59298E+02
5.00000E-02	1.29342E+01	5.56040E+01
4.80000E-02	1.25874E+01	5.24948E+01
4.60000E-02	1.22323E+01	4.94593E+01
4.40000E-02	1.18685E+01	4.64971E+01
4.20000E-02	1.14957E+01	4.36079E+01
4.00000E-02	1.11133E+01	4.07910E+01
3.80000E-02	1.07210E+01	3.80464E+01
3.60000E-02	1.03183E+01	3.53735E+01
3.40000E-02	9.90460E-00	3.27723E+01
3.20000E-02	9.47934E-00	3.02425E+01
3.00000E-02	9.04187E-00	2.77840E+01
2.80000E-02	8.59148E-00	2.53969E+01
2.60000E-02	8.12734E-00	2.30811E+01
2.40000E-02	7.64854E-00	2.08369E+01
2.20000E-02	7.15406E-00	1.86646E+01
2.00000E-02	6.64269E-00	1.65647E+01
1.80000E-02	6.11307E-00	1.45379E+01
1.60000E-02	5.56354E-00	1.25851E+01
1.40000E-02	4.99216E-00	1.07076E+01
1.20000E-02	4.39652E-00	8.90726E-00
1.00000E-02	3.77361E-00	7.18626E-00
8.00000E-03	3.11944E-00	5.54800E-00
6.00000E-03	2.42854E-00	3.99733E-00
4.00000E-03	1.69261E-00	2.54190E-00
2.00000E-03	8.97063E-01	1.19570E-00
1.00000E-03	4.67499E-01	5.72798E-01
0.00000E-99	0.00000E-99	0.00000E-99

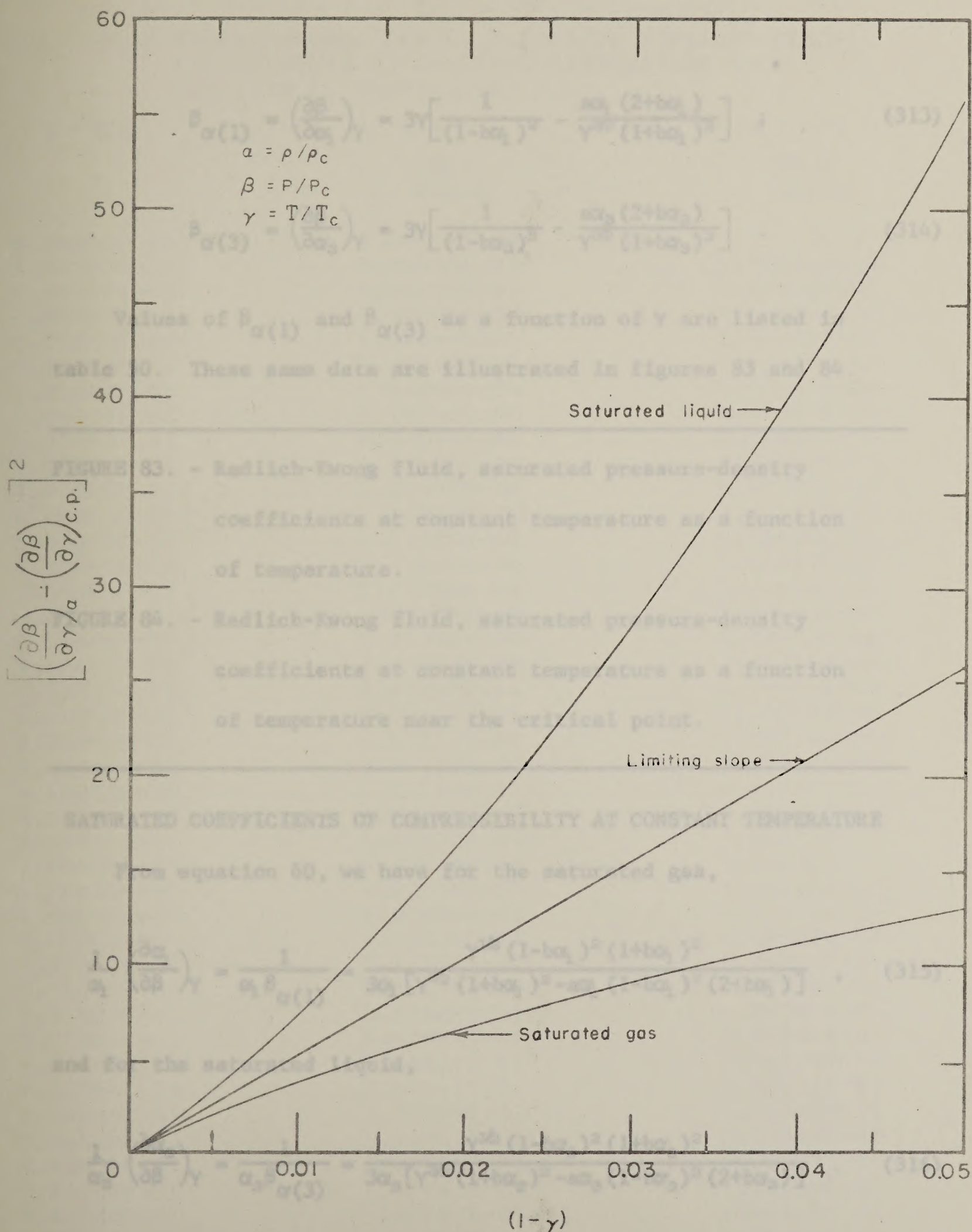


FIGURE 82. - Redlich-Kwong Fluid, Asymptotic Function of the Pressure-Temperature Coefficients at Constant Density, at Saturation, as a Function of Temperature.

$$\beta_{\alpha(1)} = \left(\frac{\partial \beta}{\partial \alpha_1} \right)_\gamma = 3\gamma \left[\frac{1}{(1-b\alpha_1)^2} - \frac{a\alpha_1 (2+b\alpha_1)}{\gamma^{3/2} (1+b\alpha_1)^2} \right] ; \quad (313)$$

$$\beta_{\alpha(3)} = \left(\frac{\partial \beta}{\partial \alpha_3} \right)_\gamma = 3\gamma \left[\frac{1}{(1-b\alpha_3)^2} - \frac{a\alpha_3 (2+b\alpha_3)}{\gamma^{3/2} (1+b\alpha_3)^2} \right] . \quad (314)$$

Values of $\beta_{\alpha(1)}$ and $\beta_{\alpha(3)}$ as a function of γ are listed in table 50. These same data are illustrated in figures 83 and 84.

FIGURE 83. - Redlich-Kwong fluid, saturated pressure-density coefficients at constant temperature as a function of temperature.

FIGURE 84. - Redlich-Kwong fluid, saturated pressure-density coefficients at constant temperature as a function of temperature near the critical point.

SATURATED COEFFICIENTS OF COMPRESSIBILITY AT CONSTANT TEMPERATURE

From equation 60, we have for the saturated gas,

$$\frac{1}{\alpha_1} \left(\frac{\partial \alpha_1}{\partial \beta} \right)_\gamma = \frac{1}{\alpha_1 \beta_{\alpha(1)}} = \frac{\gamma^{1/2} (1-b\alpha_1)^2 (1+b\alpha_1)^2}{3\alpha_1 [\gamma^{3/2} (1+b\alpha_1)^2 - a\alpha_1 (1-b\alpha_1)^2 (2+b\alpha_1)]} , \quad (315)$$

and for the saturated liquid,

$$\frac{1}{\alpha_3} \left(\frac{\partial \alpha_3}{\partial \beta} \right)_\gamma = \frac{1}{\alpha_3 \beta_{\alpha(3)}} = \frac{\gamma^{1/2} (1-b\alpha_3)^2 (1+b\alpha_3)^2}{3\alpha_3 [\gamma^{3/2} (1+b\alpha_3)^2 - a\alpha_3 (1-b\alpha_3)^2 (2+b\alpha_3)]} . \quad (316)$$

TABLE 50. - REDLICH-KWONG FLUID, SATURATED PRESSURE-DENSITY COEFFICIENTS AT CONSTANT TEMPERATURE AS A FUNCTION OF TEMPERATURE

$\gamma = T/T_c$	$\alpha = \rho/\rho_c$	$\beta = P/P_c$
γ	$\left(\frac{\partial \beta}{\partial \alpha_1}\right)_\gamma$	$\left(\frac{\partial \beta}{\partial \alpha_3}\right)_\gamma$
0.00000E-99	0.00000E-99	+ ∞
1.00000E-01	3.00000E-01	1.76721E+03
1.50000E-01	4.50000E-01	7.63576E+02
2.00000E-01	5.99999E-01	4.14918E+02
2.50000E-01	7.49999E-01	2.54919E+02
3.00000E-01	8.99999E-01	1.68835E+02
3.50000E-01	1.04996E-00	1.17467E+02
4.00000E-01	1.19946E-00	8.44995E+01
4.50000E-01	1.34631E-00	6.21632E+01
5.00000E-01	1.48472E-00	4.63860E+01
5.50000E-01	1.60497E-00	3.48702E+01
6.00000E-01	1.69514E-00	2.62436E+01
6.50000E-01	1.74329E-00	1.96471E+01
7.00000E-01	1.73871E-00	1.45217E+01
7.50000E-01	1.67205E-00	1.04913E+01
8.00000E-01	1.53474E-00	7.29603E-00
8.50000E-01	1.31784E-00	4.75327E-00
9.00000E-01	1.00984E-00	2.73469E-00
9.50000E-01	5.91165E-01	1.15588E-00
9.52000E-01	5.71613E-01	1.10119E-00
9.54000E-01	5.51811E-01	1.04715E-00
9.56000E-01	5.31752E-01	9.93760E-01
9.58000E-01	5.11430E-01	9.41014E-01
9.60000E-01	4.90839E-01	8.88919E-01
9.62000E-01	4.69972E-01	8.37477E-01
9.64000E-01	4.48820E-01	7.86692E-01
9.66000E-01	4.27376E-01	7.36569E-01
9.68000E-01	4.05630E-01	6.87112E-01
9.70000E-01	3.83573E-01	6.38328E-01
9.72000E-01	3.61192E-01	5.90225E-01
9.74000E-01	3.38475E-01	5.42810E-01
9.76000E-01	3.15409E-01	4.96094E-01
9.78000E-01	2.91977E-01	4.50089E-01
9.80000E-01	2.68161E-01	4.04809E-01
9.82000E-01	2.43941E-01	3.60272E-01
9.84000E-01	2.19291E-01	3.16498E-01
9.86000E-01	1.94183E-01	2.73514E-01
9.88000E-01	1.68580E-01	2.31351E-01
9.90000E-01	1.42437E-01	1.90050E-01
9.92000E-01	1.15697E-01	1.49667E-01
9.94000E-01	8.82789E-02	1.10279E-01
9.96000E-01	6.00615E-02	7.20025E-02
9.98000E-01	3.08347E-02	3.50443E-02
9.99000E-01	1.57076E-02	1.71938E-02
1.00000E-00	0.00000E-99	0.00000E-99

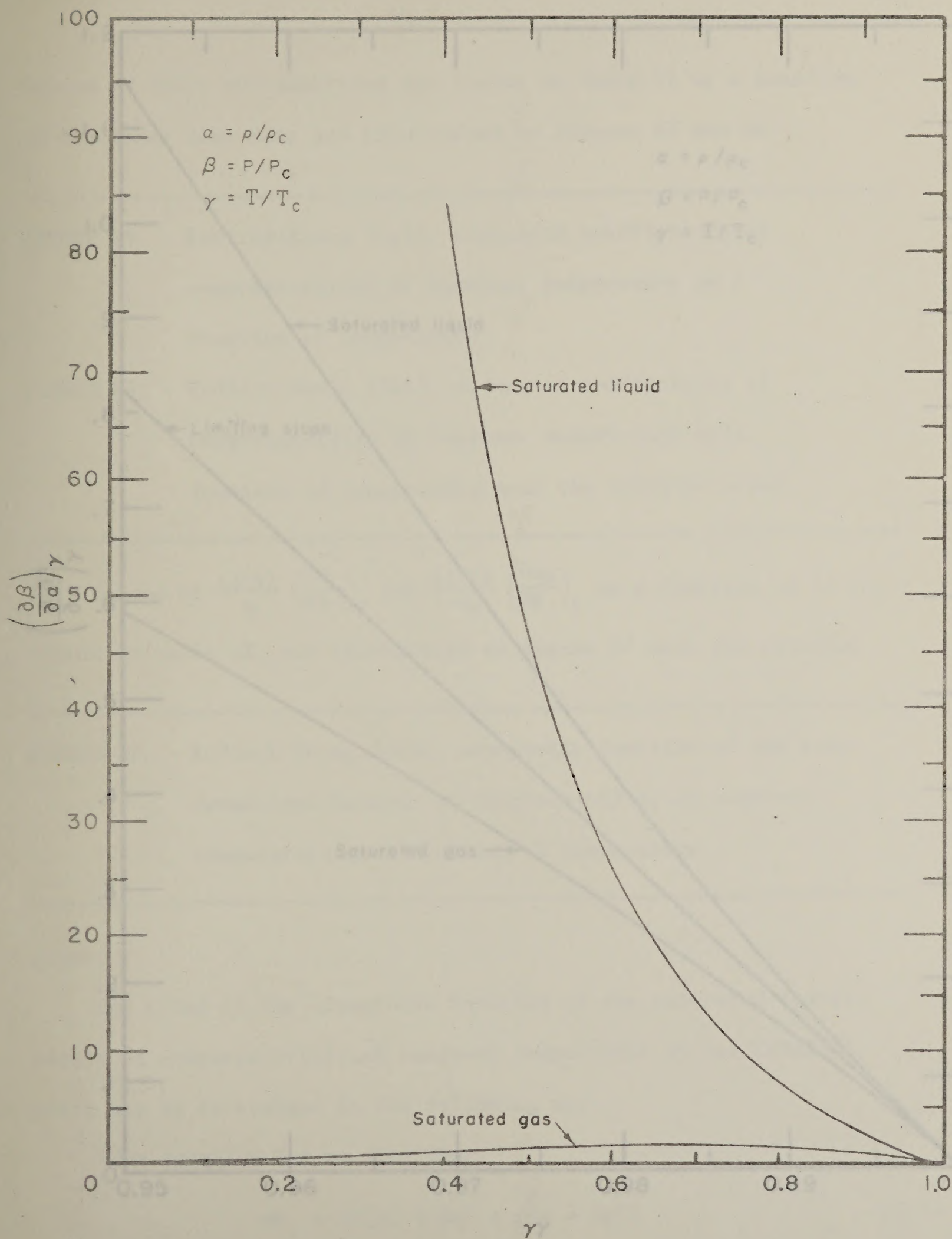


FIGURE 83. - Redlich-Kwong Fluid, Saturated Pressure-Density Coefficients at Constant Temperature as a Function of Temperature.

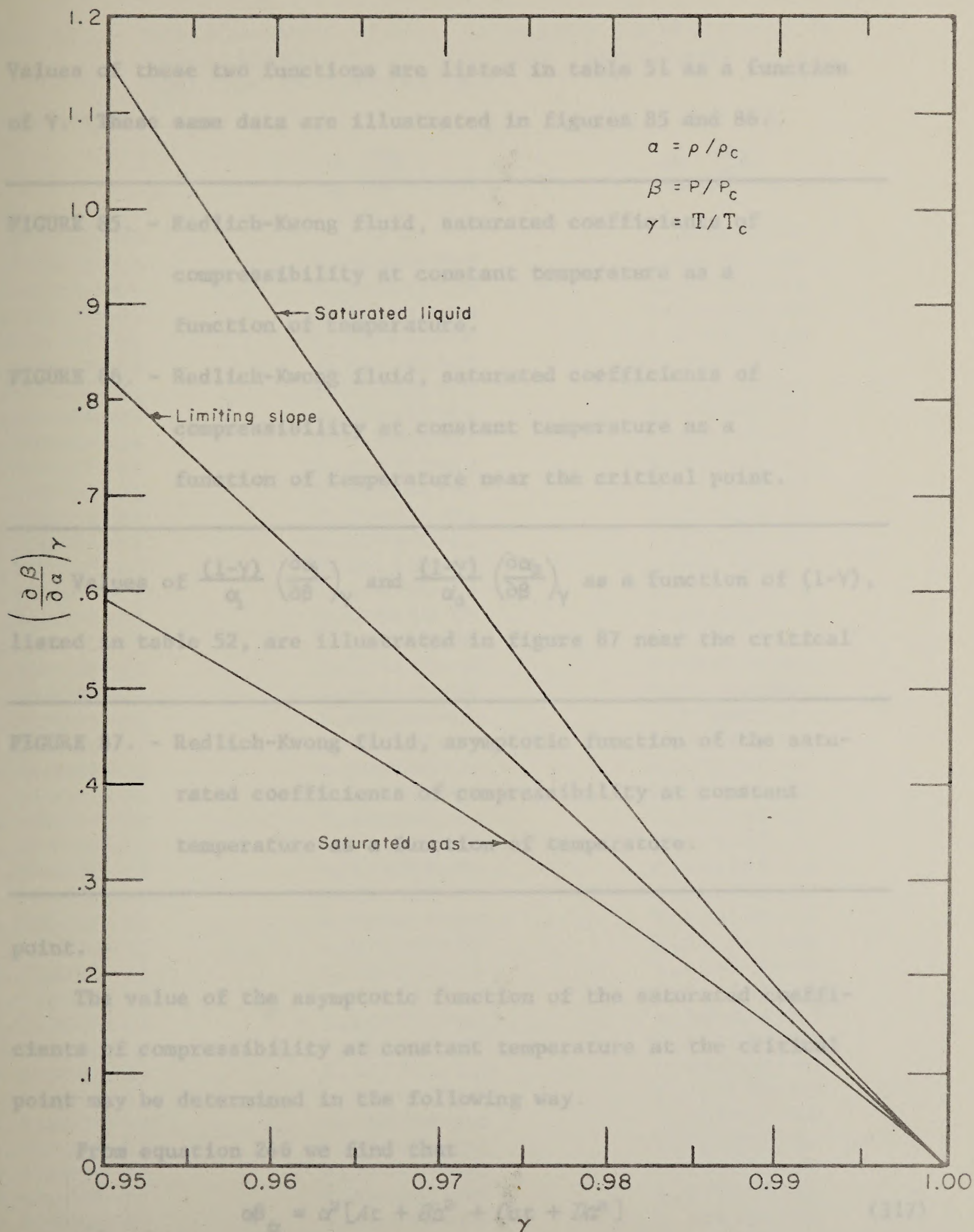


FIGURE 84. - Redlich - Kwong Fluid, Saturated Pressure - Density Coefficients at Constant Temperature as a Function of Temperature Near the Critical Point.

Values of these two functions are listed in table 51 as a function of γ . These same data are illustrated in figures 85 and 86.

FIGURE 85. - Redlich-Kwong fluid, saturated coefficients of compressibility at constant temperature as a function of temperature.

FIGURE 86. - Redlich-Kwong fluid, saturated coefficients of compressibility at constant temperature as a function of temperature near the critical point.

Values of $\frac{(1-\gamma)}{\alpha_1} \left(\frac{\partial \alpha_1}{\partial \beta} \right)_\gamma$ and $\frac{(1-\gamma)}{\alpha_3} \left(\frac{\partial \alpha_3}{\partial \beta} \right)_\gamma$ as a function of $(1-\gamma)$, listed in table 52, are illustrated in figure 87 near the critical

FIGURE 87. - Redlich-Kwong fluid, asymptotic function of the saturated coefficients of compressibility at constant temperature as a function of temperature.

point.

The value of the asymptotic function of the saturated coefficients of compressibility at constant temperature at the critical point may be determined in the following way.

From equation 246 we find that

$$\alpha\beta_\alpha = \alpha^2 [At + Ba^2 + Cat + Da^3] \quad (317)$$

TABLE 51. - REDLICH-KWONG FLUID, SATURATED COEFFICIENTS OF COMPRESSIBILITY AT CONSTANT TEMPERATURE AS A FUNCTION OF TEMPERATURE

$\gamma = T/T_c$	$\alpha = \rho/\rho_c$	$\beta = P/P_c$
γ	$\frac{1}{\alpha_1} \left(\frac{\partial \alpha_1}{\partial \beta} \right)_\gamma$	$\frac{1}{\alpha_3} \left(\frac{\partial \alpha_3}{\partial \beta} \right)_\gamma$
0.00000E-99	+ ∞	0.00000E-99
1.00000E-01	1.04268E+45	1.49002E-04
1.50000E-01	5.10216E+23	3.48711E-04
2.00000E-01	6.51678E+14	6.50474E-04
2.50000E-01	1.39263E+10	1.07561E-03
3.00000E-01	2.21828E+07	1.65373E-03
3.50000E-01	3.30996E+05	2.42615E-03
4.00000E-01	1.79418E+04	3.45155E-03
4.50000E-01	2.16965E+03	4.81510E-03
5.00000E-01	4.45079E+02	6.64393E-03
5.50000E-01	1.31408E+02	9.13385E-03
6.00000E-01	5.03432E+01	1.25981E-02
6.50000E-01	2.33944E+01	1.75625E-02
7.00000E-01	1.26153E+01	2.49650E-02
7.50000E-01	7.67419E-00	3.66211E-02
8.00000E-01	5.18669E-00	5.64601E-02
8.50000E-01	3.89095E-00	9.44929E-02
9.00000E-01	3.32317E-00	1.83989E-01
9.50000E-01	3.64283E-00	5.14759E-01
9.52000E-01	3.69573E-00	5.45096E-01
9.54000E-01	3.75473E-00	5.78434E-01
9.56000E-01	3.82060E-00	6.15214E-01
9.58000E-01	3.89422E-00	6.55961E-01
9.60000E-01	3.97668E-00	7.01311E-01
9.62000E-01	4.06928E-00	7.52040E-01
9.64000E-01	4.17359E-00	8.09105E-01
9.66000E-01	4.29156E-00	8.73695E-01
9.68000E-01	4.42562E-00	9.47310E-01
9.70000E-01	4.57880E-00	1.03186E-00
9.72000E-01	4.75503E-00	1.12984E-00
9.74000E-01	4.95937E-00	1.24453E-00
9.76000E-01	5.19855E-00	1.38033E-00
9.78000E-01	5.48170E-00	1.54332E-00
9.80000E-01	5.82150E-00	1.74208E-00
9.82000E-01	6.23616E-00	1.98915E-00
9.84000E-01	6.75279E-00	2.30351E-00
9.86000E-01	7.41362E-00	2.71537E-00
9.88000E-01	8.28848E-00	3.27565E-00
9.90000E-01	9.50184E-00	4.07723E-00
9.92000E-01	1.13000E+01	5.30847E-00
9.94000E-01	1.42509E+01	7.41579E-00
9.96000E-01	2.00336E+01	1.17628E+01
9.98000E-01	3.68846E+01	2.53276E+01
9.99000E-01	6.96549E+01	5.34085E+01
1.00000E-00	+ ∞	+ ∞

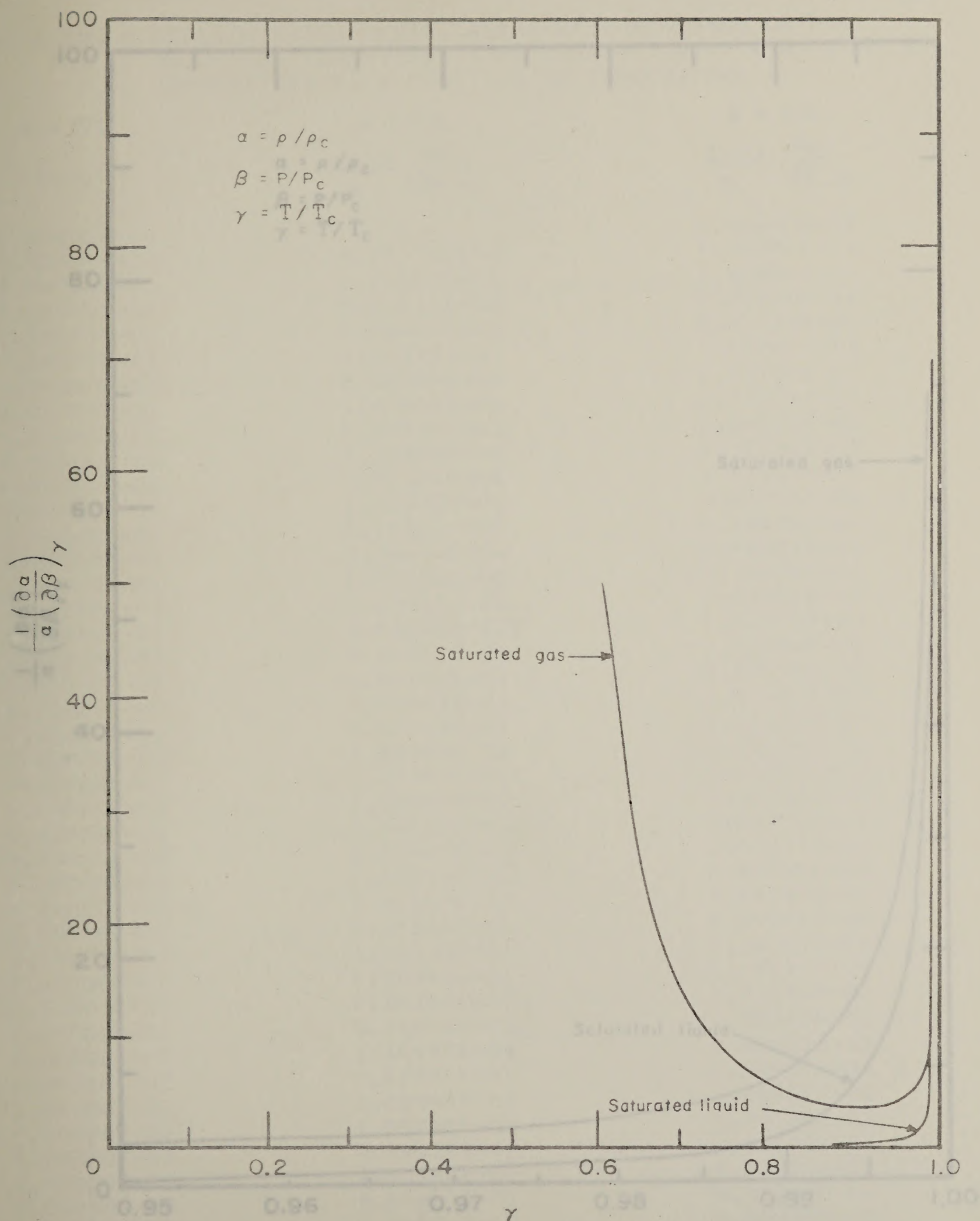


FIGURE 85.—Redlich-Kwong Fluid, Saturated Coefficients of Compressibility at Constant Temperature as a Function of Temperature.

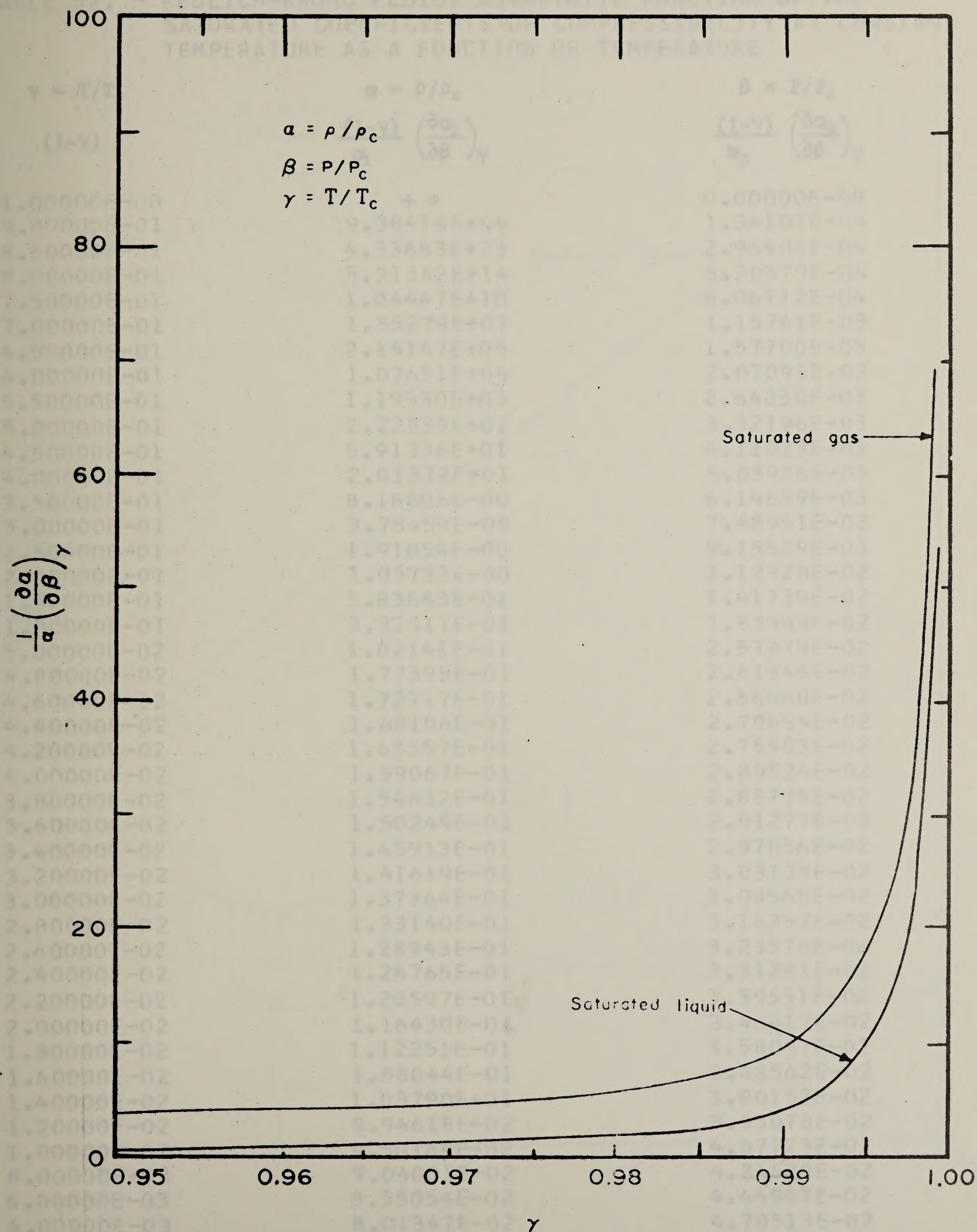


FIGURE 86.— Redlich-Kwong Fluid, Saturated Coefficients of Compressibility at Constant Temperature as a Function of Temperature Near the Critical Point.

TABLE 52. - REDLICH-KWONG FLUID, ASYMPTOTIC FUNCTION OF THE SATURATED COEFFICIENTS OF COMPRESSIBILITY AT CONSTANT TEMPERATURE AS A FUNCTION OF TEMPERATURE

$\gamma = T/T_c$	$\alpha = \rho/\rho_c$	$\beta = P/P_c$
$(1-\gamma)$	$\frac{(1-\gamma)}{\alpha_1} \left(\frac{\partial \alpha_1}{\partial \beta} \right)_\gamma$	$\frac{(1-\gamma)}{\alpha_3} \left(\frac{\partial \alpha_3}{\partial \beta} \right)_\gamma$
1.000000E-00	$+\infty$	0.000000E-99
9.000000E-01	9.38414E+44	1.34101E-04
8.500000E-01	4.33683E+23	2.96404E-04
8.000000E-01	5.21342E+14	5.20379E-04
7.500000E-01	1.04447E+10	8.06712E-04
7.000000E-01	1.55279E+07	1.15761E-03
6.500000E-01	2.15147E+05	1.57700E-03
6.000000E-01	1.07651E+04	2.07093E-03
5.500000E-01	1.19330E+03	2.64830E-03
5.000000E-01	2.22539E+02	3.32196E-03
4.500000E-01	5.91336E+01	4.11023E-03
4.000000E-01	2.01372E+01	5.03926E-03
3.500000E-01	8.18806E-00	6.14689E-03
3.000000E-01	3.78459E-00	7.48951E-03
2.500000E-01	1.91854E-00	9.15529E-03
2.000000E-01	1.03733E-00	1.12920E-02
1.500000E-01	5.83643E-01	1.41739E-02
1.000000E-01	3.32317E-01	1.83989E-02
5.000000E-02	1.82141E-01	2.57379E-02
4.800000E-02	1.77395E-01	2.61646E-02
4.600000E-02	1.72717E-01	2.66080E-02
4.400000E-02	1.68106E-01	2.70694E-02
4.200000E-02	1.63557E-01	2.75503E-02
4.000000E-02	1.59067E-01	2.80524E-02
3.800000E-02	1.54632E-01	2.85775E-02
3.600000E-02	1.50249E-01	2.91277E-02
3.400000E-02	1.45913E-01	2.97056E-02
3.200000E-02	1.41619E-01	3.03139E-02
3.000000E-02	1.37364E-01	3.09560E-02
2.800000E-02	1.33140E-01	3.16357E-02
2.600000E-02	1.28943E-01	3.23579E-02
2.400000E-02	1.24765E-01	3.31281E-02
2.200000E-02	1.20597E-01	3.39531E-02
2.000000E-02	1.16430E-01	3.48417E-02
1.800000E-02	1.12251E-01	3.58047E-02
1.600000E-02	1.08044E-01	3.68562E-02
1.400000E-02	1.03790E-01	3.80152E-02
1.200000E-02	9.94618E-02	3.93078E-02
1.000000E-02	9.50184E-02	4.07723E-02
8.000000E-03	9.04001E-02	4.24678E-02
6.000000E-03	8.55054E-02	4.44947E-02
4.000000E-03	8.01347E-02	4.70513E-02
2.000000E-03	7.37693E-02	5.06553E-02
1.000000E-03	6.96549E-02	5.34085E-02
0.000000E-99	6.08574E-02	6.08574E-02

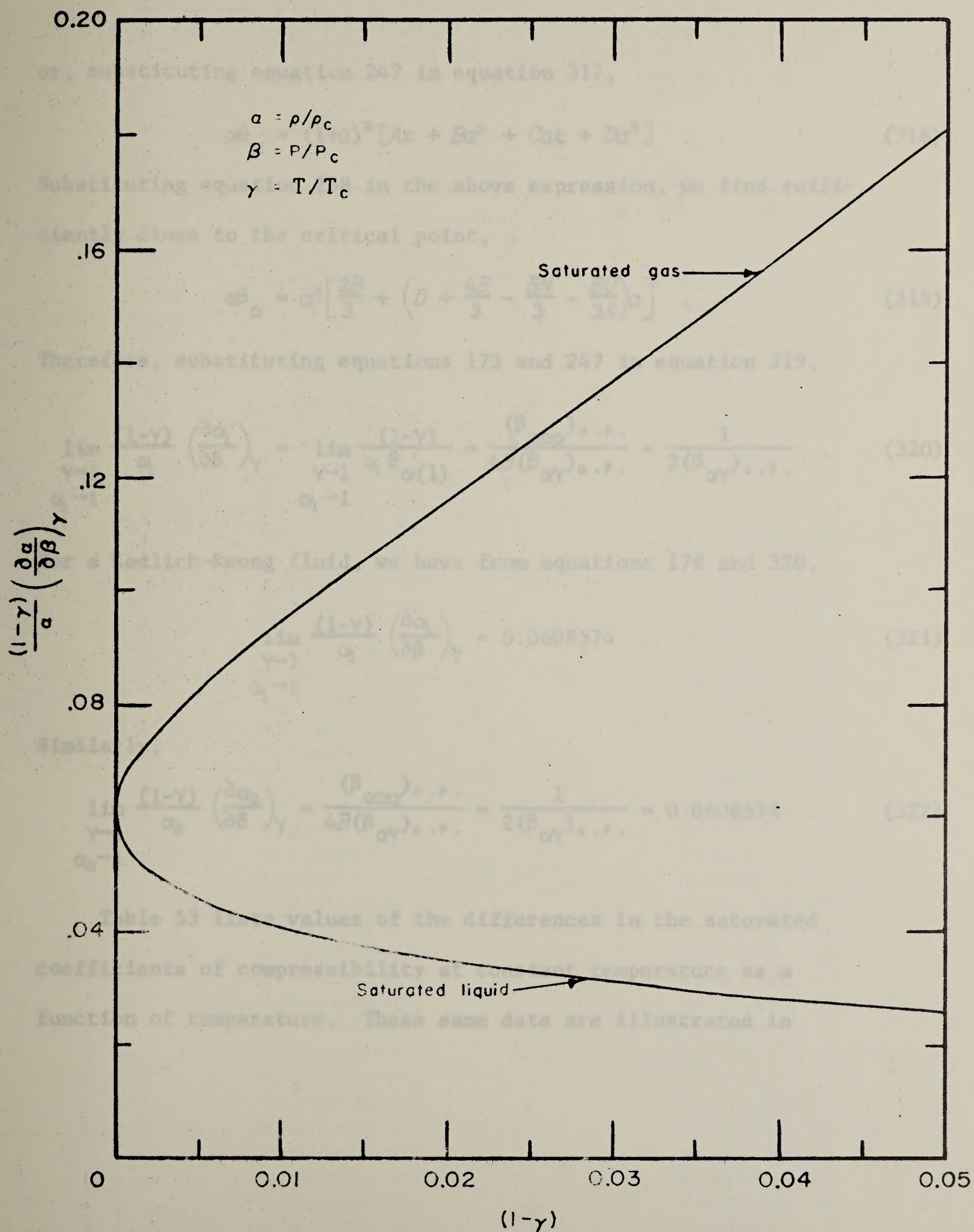


FIGURE 87.—Redlich-Kwong Fluid, Asymptotic Function of the Saturated Coefficients of Compressibility at Constant Temperature as a Function of Temperature.

or, substituting equation 247 in equation 317,

$$\alpha\beta_{\alpha} = (1+\alpha)^2 [At + B\alpha^2 + C\alpha t + D\alpha^3] \quad (318)$$

Substituting equation 258 in the above expression, we find sufficiently close to the critical point,

$$\alpha\beta_{\alpha} = \alpha^2 \left[\frac{2B}{3} + \left(D + \frac{4B}{3} - \frac{BM}{3} - \frac{BC}{3A} \right) \alpha \right] \quad (319)$$

Therefore, substituting equations 173 and 247 in equation 319,

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha_1 \rightarrow 1}} \frac{(1-\gamma)}{\alpha_1} \left(\frac{\partial \alpha_1}{\partial \beta} \right)_{\gamma} = \lim_{\substack{\gamma \rightarrow 1 \\ \alpha_1 \rightarrow 1}} \frac{(1-\gamma)}{\alpha_1 \beta_{\alpha(1)}} = \frac{(\beta_{\alpha\alpha\alpha})_{c.p.}}{4B(\beta_{\alpha\gamma})_{c.p.}} = \frac{1}{2(\beta_{\alpha\gamma})_{c.p.}} \quad (320)$$

For a Redlich-Kwong fluid, we have from equations 178 and 320,

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha_1 \rightarrow 1}} \frac{(1-\gamma)}{\alpha_1} \left(\frac{\partial \alpha_1}{\partial \beta} \right)_{\gamma} = 0.0608574 \quad (321)$$

Similarly,

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha_3 \rightarrow 1}} \frac{(1-\gamma)}{\alpha_3} \left(\frac{\partial \alpha_3}{\partial \beta} \right)_{\gamma} = \frac{(\beta_{\alpha\alpha\alpha})_{c.p.}}{4B(\beta_{\alpha\gamma})_{c.p.}} = \frac{1}{2(\beta_{\alpha\gamma})_{c.p.}} = 0.0608574 \quad (322)$$

Table 53 lists values of the differences in the saturated coefficients of compressibility at constant temperature as a function of temperature. These same data are illustrated in

TABLE 53. - REDLICH-KWONG FLUID, DIFFERENCES IN THE SATURATED COEFFICIENTS OF COMPRESSIBILITY AT CONSTANT TEMPERATURE AS A FUNCTION OF TEMPERATURE

$$\gamma = T/T_c$$

$$\alpha = \rho/\rho_c$$

$$\beta = P/P_c$$

 γ

$$\left[\frac{1}{\alpha_1} \left(\frac{\partial \alpha_1}{\partial \beta} \right)_{\gamma} - \frac{1}{\alpha_3} \left(\frac{\partial \alpha_3}{\partial \beta} \right)_{\gamma} \right]$$

0.000000E-99	+ ∞
1.000000E-01	1.04268E+45
1.500000E-01	5.10216E+23
2.000000E-01	6.51678E+14
2.500000E-01	1.39263E+10
3.000000E-01	2.21828E+07
3.500000E-01	3.30996E+05
4.000000E-01	1.79418E+04
4.500000E-01	2.16965E+03
5.000000E-01	4.45072E+02
5.500000E-01	1.31398E+02
6.000000E-01	5.03306E+01
6.500000E-01	2.33769E+01
7.000000E-01	1.25903E+01
7.500000E-01	7.63757E-00
8.000000E-01	5.13023E-00
8.500000E-01	3.79646E-00
9.000000E-01	3.13918E-00
9.500000E-01	3.12807E-00
9.520000E-01	3.15063E-00
9.540000E-01	3.17630E-00
9.560000E-01	3.20538E-00
9.580000E-01	3.23826E-00
9.600000E-01	3.27537E-00
9.620000E-01	3.31724E-00
9.640000E-01	3.36448E-00
9.660000E-01	3.41786E-00
9.680000E-01	3.47830E-00
9.700000E-01	3.54694E-00
9.720000E-01	3.62518E-00
9.740000E-01	3.71483E-00
9.760000E-01	3.81821E-00
9.780000E-01	3.93837E-00
9.800000E-01	4.07941E-00
9.820000E-01	4.24701E-00
9.840000E-01	4.44927E-00
9.860000E-01	4.69825E-00
9.880000E-01	5.01282E-00
9.900000E-01	5.42460E-00
9.920000E-01	5.99154E-00
9.940000E-01	6.83511E-00
9.960000E-01	8.27084E-00
9.980000E-01	1.15569E+01
9.990000E-01	1.62464E+01
1.000000E-00	+ ∞

figures 88 and 89.

FIGURE 88. - Redlich-Kwong fluid, differences in the saturated coefficients of compressibility at constant temperature as a function of temperature.

FIGURE 89. - Redlich-Kwong fluid, differences in the saturated coefficients of compressibility at constant temperature as a function of temperature near the critical point.

The limiting value of the differences in the saturated coefficients of compressibility at constant temperature as the critical point is approached may be determined in the following way.

From equation 319, we find

$$\alpha_1 \beta_{\alpha(1)} = \frac{2B}{3} \alpha_1^2 \left[1 + \left(\frac{3D}{2B} + 2 - \frac{M}{2} - \frac{C}{2A} \right) \alpha_1 \right] ; \quad (323)$$

$$\alpha_3 \beta_{\alpha(3)} = \frac{2B}{3} \alpha_3^2 \left[1 + \left(\frac{3D}{2B} + 2 - \frac{M}{2} - \frac{C}{2A} \right) \alpha_3 \right] . \quad (324)$$

Substituting equation 272 in equation 324, ignoring terms of the order of α_1^4 and higher,

$$\alpha_3 \beta_{\alpha(3)} = \frac{2B}{3} \alpha_1^2 \left[1 + \left(\frac{5M}{2} + \frac{C}{2A} - 2 - \frac{3D}{2B} \right) \alpha_1 \right] . \quad (325)$$

Subtracting equations 323 and 325,

$$\alpha_3 \beta_{\alpha(3)} - \alpha_1 \beta_{\alpha(1)} = \frac{2B}{3} \alpha_1^3 \left[3M + \frac{C}{A} - 4 - \frac{3D}{B} \right] . \quad (326)$$

FIGURE 88.-Redlich-Kwong Fluid, Differences in the Saturated Coefficients of Compressibility at Constant Temperature as a Function of Temperature.

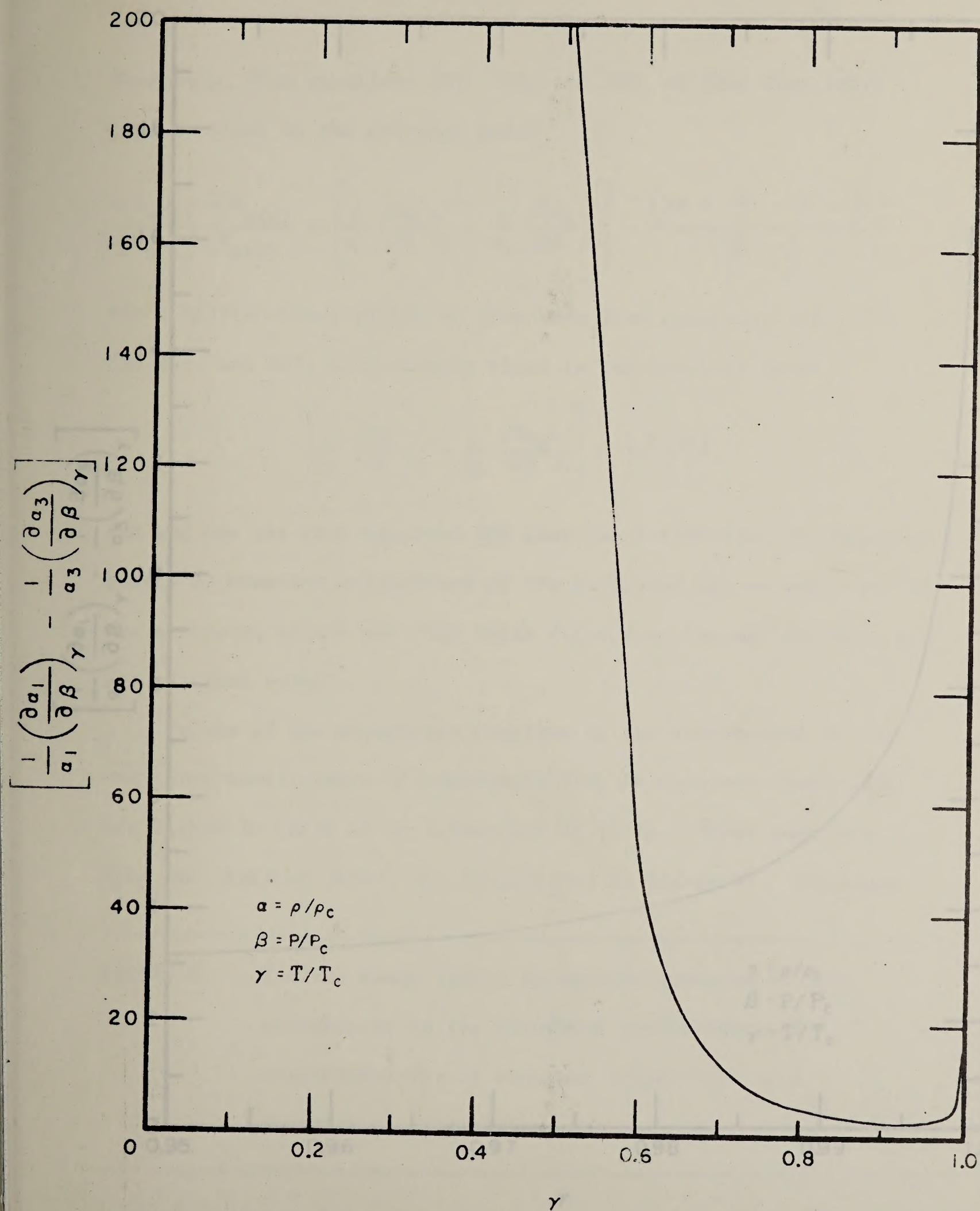


FIGURE 88.—Redlich-Kwong Fluid, Differences in the Saturated Coefficients of Compressibility at Constant Temperature as a Function of Temperature.

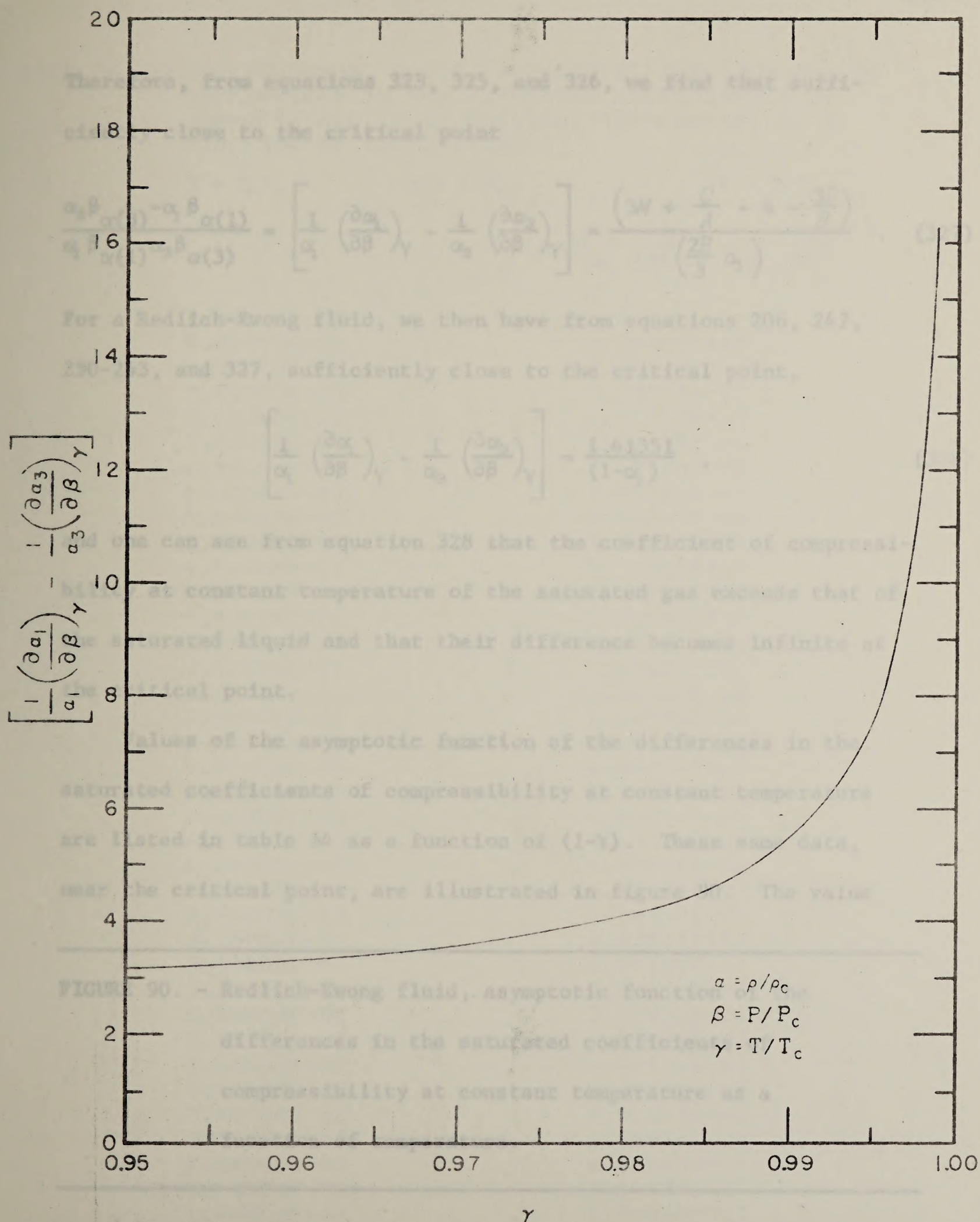


FIGURE 89.-Redlich-Kwong Fluid, Differences in the Saturated Coefficients of Compressibility at Constant Temperature as a Function of Temperature Near the Critical Point.

Therefore, from equations 323, 325, and 326, we find that sufficiently close to the critical point

$$\frac{\alpha_3 \beta_{\alpha(3)}^{-\alpha_1 \beta_{\alpha(1)}}}{\alpha_1 \beta_{\alpha(1)} \alpha_3 \beta_{\alpha(3)}} = \left[\frac{1}{\alpha_1} \left(\frac{\partial \alpha_1}{\partial \beta} \right)_\gamma - \frac{1}{\alpha_3} \left(\frac{\partial \alpha_3}{\partial \beta} \right)_\gamma \right] = \frac{\left(3M + \frac{C}{A} - 4 - \frac{3D}{B} \right)}{\left(\frac{2B}{3} \alpha_1 \right)}. \quad (327)$$

For a Redlich-Kwong fluid, we then have from equations 206, 247, 250-253, and 327, sufficiently close to the critical point,

$$\left[\frac{1}{\alpha_1} \left(\frac{\partial \alpha_1}{\partial \beta} \right)_\gamma - \frac{1}{\alpha_3} \left(\frac{\partial \alpha_3}{\partial \beta} \right)_\gamma \right] = \frac{1.41351}{(1-\alpha_1)}, \quad (328)$$

and one can see from equation 328 that the coefficient of compressibility at constant temperature of the saturated gas exceeds that of the saturated liquid and that their difference becomes infinite at the critical point.

Values of the asymptotic function of the differences in the saturated coefficients of compressibility at constant temperature are listed in table 54 as a function of $(1-\gamma)$. These same data, near the critical point, are illustrated in figure 90. The value

FIGURE 90. - Redlich-Kwong fluid, asymptotic function of the differences in the saturated coefficients of compressibility at constant temperature as a function of temperature.

TABLE 54. - REDLICH-KWONG FLUID, ASYMPTOTIC FUNCTION OF THE DIFFERENCES IN THE SATURATED COEFFICIENTS OF COMPRESSIBILITY AT CONSTANT TEMPERATURE AS A FUNCTION OF TEMPERATURE

$$\gamma = T/T_c$$

$$\alpha = \rho/\rho_c$$

$$\beta = P/P_c$$

$$(1-\gamma)$$

$$(1-\gamma) \left[\frac{1}{\alpha_1} \left(\frac{\partial \alpha_1}{\partial \beta} \right)_{\gamma} - \frac{1}{\alpha_3} \left(\frac{\partial \alpha_3}{\partial \beta} \right)_{\gamma} \right]^2$$

1.00000E-00

+ ∞

9.00000E-01

9.78468E+89

8.50000E-01

2.21272E+47

8.00000E-01

3.39748E+29

7.50000E-01

1.45457E+20

7.00000E-01

3.44455E+14

6.50000E-01

7.12130E+10

6.00000E-01

1.93146E+08

5.50000E-01

2.58905E+06

5.00000E-01

9.90449E+04

4.50000E-01

7.76956E+03

4.00000E-01

1.01326E+03

3.50000E-01

1.91268E+02

3.00000E-01

4.75551E+01

2.50000E-01

1.45831E+01

2.00000E-01

5.26386E-00

1.50000E-01

2.16196E-00

1.00000E-01

9.85449E-01

5.00000E-02

4.89242E-01

4.80000E-02

4.76473E-01

4.60000E-02

4.64089E-01

4.40000E-02

4.52078E-01

4.20000E-02

4.40426E-01

4.00000E-02

4.29123E-01

3.80000E-02

4.18155E-01

3.60000E-02

4.07511E-01

3.40000E-02

3.97182E-01

3.20000E-02

3.87156E-01

3.00000E-02

3.77423E-01

2.80000E-02

3.67974E-01

2.60000E-02

3.58799E-01

2.40000E-02

3.49890E-01

2.20000E-02

3.41237E-01

2.00000E-02

3.32833E-01

1.80000E-02

3.24668E-01

1.60000E-02

3.16737E-01

1.40000E-02

3.09030E-01

1.20000E-02

3.01541E-01

1.00000E-02

2.94263E-01

8.00000E-03

2.87188E-01

6.00000E-03

2.80312E-01

4.00000E-03

2.73627E-01

2.00000E-03

2.67128E-01

1.00000E-03

2.63946E-01

0.00000E-99

2.60808E-01

FIGURE 54. - REDLICH-KWONG FLUID, ASYMPTOTIC FUNCTION OF THE DIFFERENCES IN THE SATURATED COEFFICIENTS OF COMPRESSIBILITY AT CONSTANT TEMPERATURE AS A FUNCTION OF TEMPERATURE.

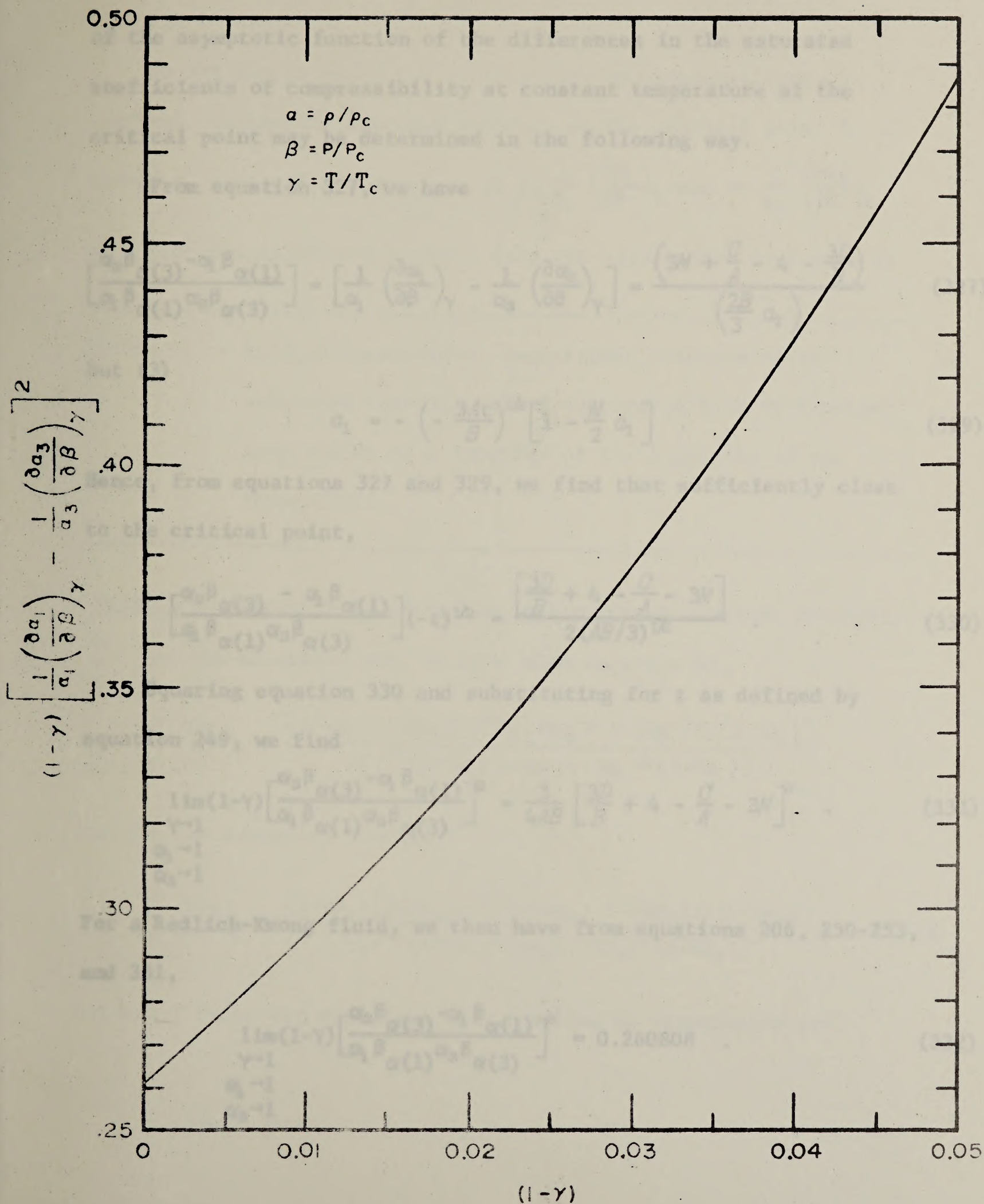


FIGURE 90.—Redlich-Kwong Fluid, Asymptotic Function of the Differences in the Saturated Coefficients of Compressibility at Constant Temperature as a Function of Temperature.

of the asymptotic function of the differences in the saturated coefficients of compressibility at constant temperature at the critical point may be determined in the following way.

From equation 327, we have

$$\left[\frac{\alpha_3 \beta_{\alpha(3)} - \alpha_1 \beta_{\alpha(1)}}{\alpha_1 \beta_{\alpha(1)} \alpha_3 \beta_{\alpha(3)}} \right] = \left[\frac{1}{\alpha_1} \left(\frac{\partial \alpha_1}{\partial \beta} \right)_\gamma - \frac{1}{\alpha_3} \left(\frac{\partial \alpha_3}{\partial \beta} \right)_\gamma \right] = \frac{\left(3M + \frac{C}{A} - 4 - \frac{3D}{B} \right)}{\left(\frac{2B}{3} \alpha_1 \right)} \quad (327)$$

But (3)

$$\alpha_1 = - \left(- \frac{3At}{B} \right)^{1/2} \left[1 - \frac{M}{2} \alpha_1 \right] \quad (329)$$

Hence, from equations 327 and 329, we find that sufficiently close to the critical point,

$$\left[\frac{\alpha_3 \beta_{\alpha(3)} - \alpha_1 \beta_{\alpha(1)}}{\alpha_1 \beta_{\alpha(1)} \alpha_3 \beta_{\alpha(3)}} \right] (-t)^{1/2} = \frac{\left[\frac{3D}{B} + 4 - \frac{C}{A} - 3M \right]}{2(AB/3)^{1/2}} \quad (330)$$

Squaring equation 330 and substituting for t as defined by equation 249, we find

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha_1 \rightarrow 1 \\ \alpha_3 \rightarrow 1}} (1-\gamma) \left[\frac{\alpha_3 \beta_{\alpha(3)} - \alpha_1 \beta_{\alpha(1)}}{\alpha_1 \beta_{\alpha(1)} \alpha_3 \beta_{\alpha(3)}} \right]^2 = \frac{3}{4AB} \left[\frac{3D}{B} + 4 - \frac{C}{A} - 3M \right]^2 \quad (331)$$

For a Redlich-Kwong fluid, we then have from equations 206, 250-253, and 331,

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha_1 \rightarrow 1 \\ \alpha_3 \rightarrow 1}} (1-\gamma) \left[\frac{\alpha_3 \beta_{\alpha(3)} - \alpha_1 \beta_{\alpha(1)}}{\alpha_1 \beta_{\alpha(1)} \alpha_3 \beta_{\alpha(3)}} \right]^2 = 0.260808 \quad (332)$$

As the way in which the coefficients of compressibility at constant temperature approach infinity at the critical point is of interest, table 55 lists values of $\ln \frac{1}{\alpha_1} \left(\frac{\partial \alpha_1}{\partial \beta} \right)_\gamma$ and $\ln \frac{1}{\alpha_3} \left(\frac{\partial \alpha_3}{\partial \beta} \right)_\gamma$ as a function of $\ln(1-\gamma)$. These data are illustrated in figure 91.

FIGURE 91. - Redlich-Kwong fluid, logarithmic function of the saturated coefficients of compressibility at constant temperature as a function of the logarithm of the temperature.

SATURATED COEFFICIENTS OF THERMAL EXPANSION AT CONSTANT PRESSURE

For the saturated gas, we have from equation 63,

$$-\frac{1}{\alpha_1} \left(\frac{\partial \alpha_1}{\partial \gamma} \right)_\beta = \frac{(1-b\alpha_1)(1+b\alpha_1)[\gamma^{3/2}(1+b\alpha_1) + (a\alpha_1/2)(1-b\alpha_1)]}{\gamma[\gamma^{3/2}(1+b\alpha_1)^2 - a\alpha_1(1-b\alpha_1)^2(2+b\alpha_1)]}, \quad (333)$$

and for the saturated liquid,

$$-\frac{1}{\alpha_3} \left(\frac{\partial \alpha_3}{\partial \gamma} \right)_\beta = \frac{(1-b\alpha_3)(1+b\alpha_3)[\gamma^{3/2}(1+b\alpha_3) + (a\alpha_3/2)(1-b\alpha_3)]}{\gamma[\gamma^{3/2}(1+b\alpha_3)^2 - a\alpha_3(1-b\alpha_3)^2(2+b\alpha_3)]}. \quad (334)$$

Values of these two functions as a function of temperature are

TABLE 55. - REDLICH-KWONG FLUID, LOGARITHMIC FUNCTION OF THE SATURATED COEFFICIENTS OF COMPRESSIBILITY AT CONSTANT TEMPERATURE AS A FUNCTION OF THE LOGARITHM OF THE TEMPERATURE

$\gamma = T/T_c$ $\ln(1-\gamma)$	$\alpha = p/p_c$ $\ln \frac{1}{\alpha_1} \left(\frac{\partial \alpha_1}{\partial \beta} \right)_{\gamma}$	$\beta = P/P_c$ $\ln \frac{1}{\alpha_3} \left(\frac{\partial \alpha_3}{\partial \beta} \right)_{\gamma}$
0.000000E-99	+ ∞	- ∞
-1.05360E-01	1.03658E+02	-8.81155E-00
-1.62518E-01	5.45891E+01	-7.96126E-00
-2.23143E-01	3.41105E+01	-7.33780E-00
-2.87682E-01	2.33570E+01	-6.83486E-00
-3.56674E-01	1.69148E+01	-6.40472E-00
-4.30782E-01	1.27098E+01	-6.02144E-00
-5.10825E-01	9.79489E-00	-5.66892E-00
-5.97837E-01	7.68232E-00	-5.33599E-00
-6.93147E-01	6.09825E-00	-5.01405E-00
-7.98507E-01	4.87830E-00	-4.69576E-00
-9.16290E-01	3.91886E-00	-4.37420E-00
-1.04982E-00	3.15250E-00	-4.04198E-00
-1.20397E-00	2.53491E-00	-3.69027E-00
-1.38629E-00	2.03786E-00	-3.30712E-00
-1.60943E-00	1.64609E-00	-2.87421E-00
-1.89711E-00	1.35865E-00	-2.35923E-00
-2.30258E-00	1.20092E-00	-1.69287E-00
-2.99573E-00	1.29276E-00	-6.64055E-01
-3.03655E-00	1.30717E-00	-6.06793E-01
-3.07911E-00	1.32301E-00	-5.47429E-01
-3.12356E-00	1.34040E-00	-4.85784E-01
-3.17008E-00	1.35949E-00	-4.21653E-01
-3.21887E-00	1.38044E-00	-3.54803E-01
-3.27016E-00	1.40346E-00	-2.84965E-01
-3.32423E-00	1.42877E-00	-2.11826E-01
-3.38139E-00	1.45665E-00	-1.35023E-01
-3.44201E-00	1.48741E-00	-5.41282E-02
-3.50655E-00	1.52143E-00	3.13701E-02
-3.57555E-00	1.55920E-00	1.22084E-01
-3.64965E-00	1.60127E-00	2.18762E-01
-3.72970E-00	1.64838E-00	3.22328E-01
-3.81671E-00	1.70141E-00	4.33940E-01
-3.91202E-00	1.76155E-00	5.55084E-01
-4.01738E-00	1.83036E-00	6.87708E-01
-4.13516E-00	1.90995E-00	8.34436E-01
-4.26869E-00	2.00331E-00	9.98929E-01
-4.42284E-00	2.11486E-00	1.18651E-00
-4.60517E-00	2.25148E-00	1.40541E-00
-4.82831E-00	2.42480E-00	1.66930E-00
-5.11599E-00	2.65682E-00	2.00361E-00
-5.52146E-00	2.99741E-00	2.46494E-00
-6.21460E-00	3.60779E-00	3.23189E-00
-6.90775E-00	4.24355E-00	3.97796E-00
- ∞	+ ∞	+ ∞

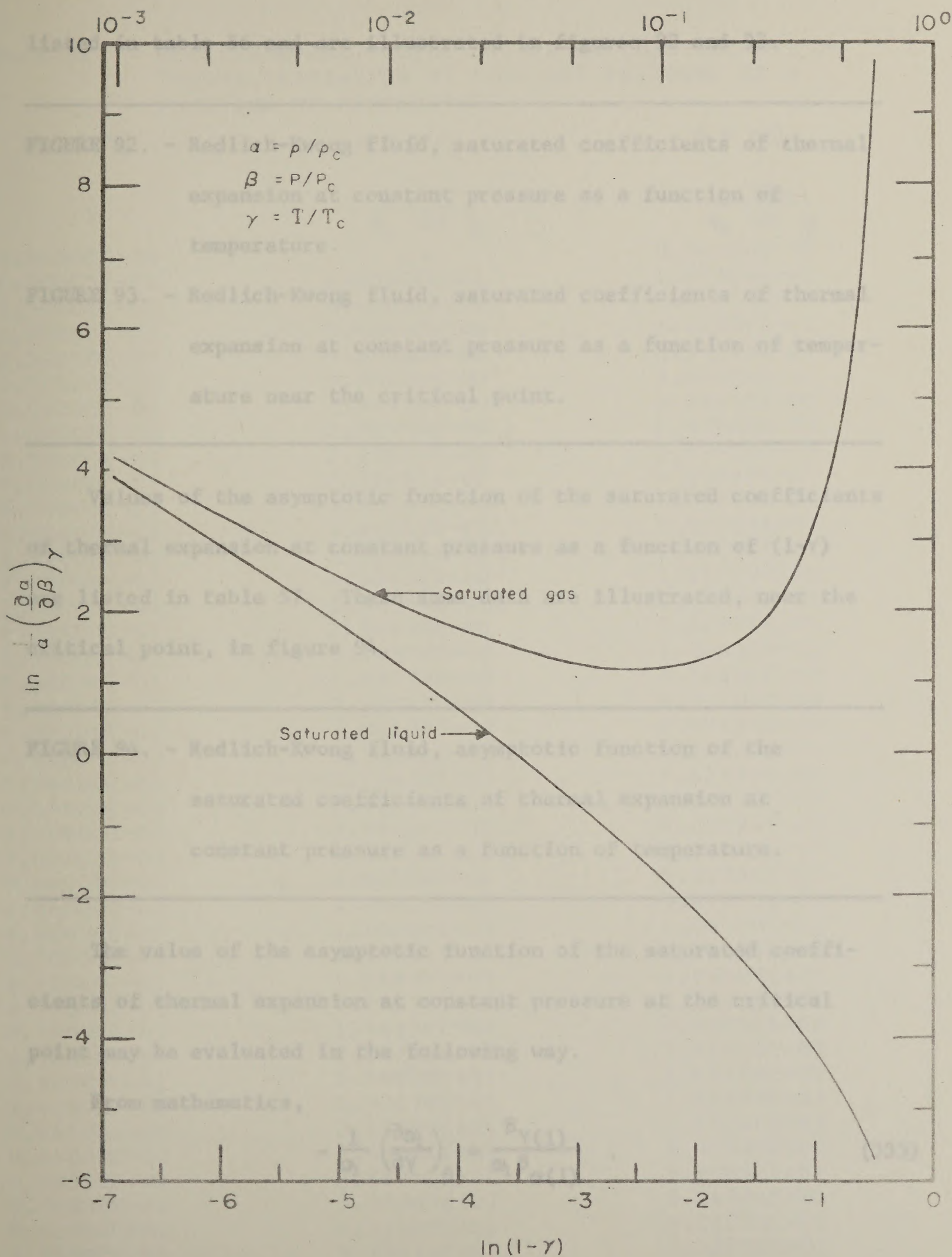
$(1-\gamma)$ 

FIGURE 91.—Redlich-Kwong Fluid, Logarithmic Function of the Saturated Coefficients of Compressibility at Constant Temperature as a Function of the Logarithm of the Temperature.

listed in table 56 and are illustrated in figures 92 and 93.

FIGURE 92. - Redlich-Kwong fluid, saturated coefficients of thermal expansion at constant pressure as a function of temperature.

FIGURE 93. - Redlich-Kwong fluid, saturated coefficients of thermal expansion at constant pressure as a function of temperature near the critical point.

Values of the asymptotic function of the saturated coefficients of thermal expansion at constant pressure as a function of $(1-Y)$ are listed in table 57. These same data are illustrated, near the critical point, in figure 94.

FIGURE 94. - Redlich-Kwong fluid, asymptotic function of the saturated coefficients of thermal expansion at constant pressure as a function of temperature.

The value of the asymptotic function of the saturated coefficients of thermal expansion at constant pressure at the critical point may be evaluated in the following way.

From mathematics,

$$-\frac{1}{\alpha_1} \left(\frac{\partial \alpha_1}{\partial Y} \right)_{\beta} = \frac{\beta_Y(1)}{\alpha_1 \beta_{\alpha(1)}} \quad (335)$$

TABLE 56. - REDLICH-KWONG FLUID, SATURATED COEFFICIENTS OF THERMAL EXPANSION AT CONSTANT PRESSURE AS A FUNCTION OF TEMPERATURE

$\gamma = T/T_c$	$\alpha = \rho/\rho_c$	$\beta = P/P_c$
γ	$-\frac{1}{\alpha_1} \left(\frac{\partial \alpha_1}{\partial \gamma} \right)_\beta$	$-\frac{1}{\alpha_3} \left(\frac{\partial \alpha_3}{\partial \gamma} \right)_\beta$
0.00000E-99	$+\infty$	0.00000E-99
1.00000E-01	1.00000E+01	1.97360E-01
1.50000E-01	6.66666E-00	2.47239E-01
2.00000E-01	5.00000E-00	2.93506E-01
2.50000E-01	4.00000E-00	3.39078E-01
3.00000E-01	3.33333E-00	3.85844E-01
3.50000E-01	2.85726E-00	4.35410E-01
4.00000E-01	2.50144E-00	4.89440E-01
4.50000E-01	2.23012E-00	5.49920E-01
5.00000E-01	2.02691E-00	6.19439E-01
5.50000E-01	1.88541E-00	7.01593E-01
6.00000E-01	1.80369E-00	8.01642E-01
6.50000E-01	1.78321E-00	9.27716E-01
7.00000E-01	1.83121E-00	1.09323E-00
7.50000E-01	1.96659E-00	1.32224E-00
8.00000E-01	2.23379E-00	1.66267E-00
8.50000E-01	2.74374E-00	2.22637E-00
9.00000E-01	3.83719E-00	3.34894E-00
9.50000E-01	7.22741E-00	6.71104E-00
9.52000E-01	7.51175E-00	6.99127E-00
9.54000E-01	7.82092E-00	7.29589E-00
9.56000E-01	8.15832E-00	7.62824E-00
9.58000E-01	8.52795E-00	7.99227E-00
9.60000E-01	8.93466E-00	8.39274E-00
9.62000E-01	9.38429E-00	8.83543E-00
9.64000E-01	9.88398E-00	9.32736E-00
9.66000E-01	1.04425E+01	9.87725E-00
9.68000E-01	1.10710E+01	1.04959E+01
9.70000E-01	1.17833E+01	1.11973E+01
9.72000E-01	1.25975E+01	1.19989E+01
9.74000E-01	1.35370E+01	1.29241E+01
9.76000E-01	1.46330E+01	1.40037E+01
9.78000E-01	1.59283E+01	1.52800E+01
9.80000E-01	1.74825E+01	1.68118E+01
9.82000E-01	1.93818E+01	1.86846E+01
9.84000E-01	2.17555E+01	2.10264E+01
9.86000E-01	2.48068E+01	2.40383E+01
9.88000E-01	2.88741E+01	2.80557E+01
9.90000E-01	3.45663E+01	3.36826E+01
9.92000E-01	4.31009E+01	4.21273E+01
9.94000E-01	5.73179E+01	5.62099E+01
9.96000E-01	8.57327E+01	8.43957E+01
9.98000E-01	1.70897E+02	1.69034E+02
9.99000E-01	3.41078E+02	3.38463E+02
1.00000E-00	$+\infty$	$+\infty$

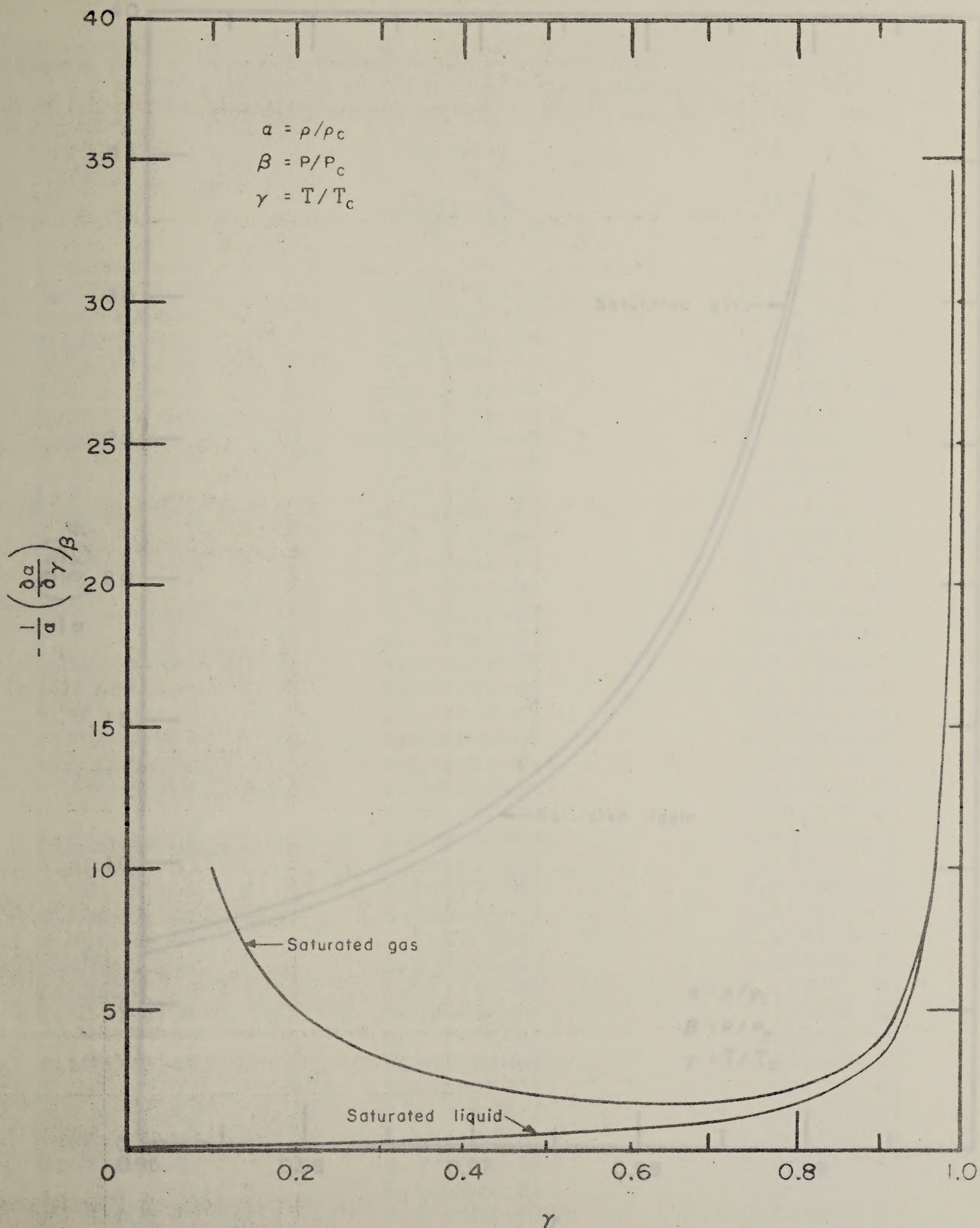


FIGURE 92.—Redlich-Kwong Fluid, Saturated Coefficients of Thermal Expansion at Constant Pressure as a Function of Temperature.

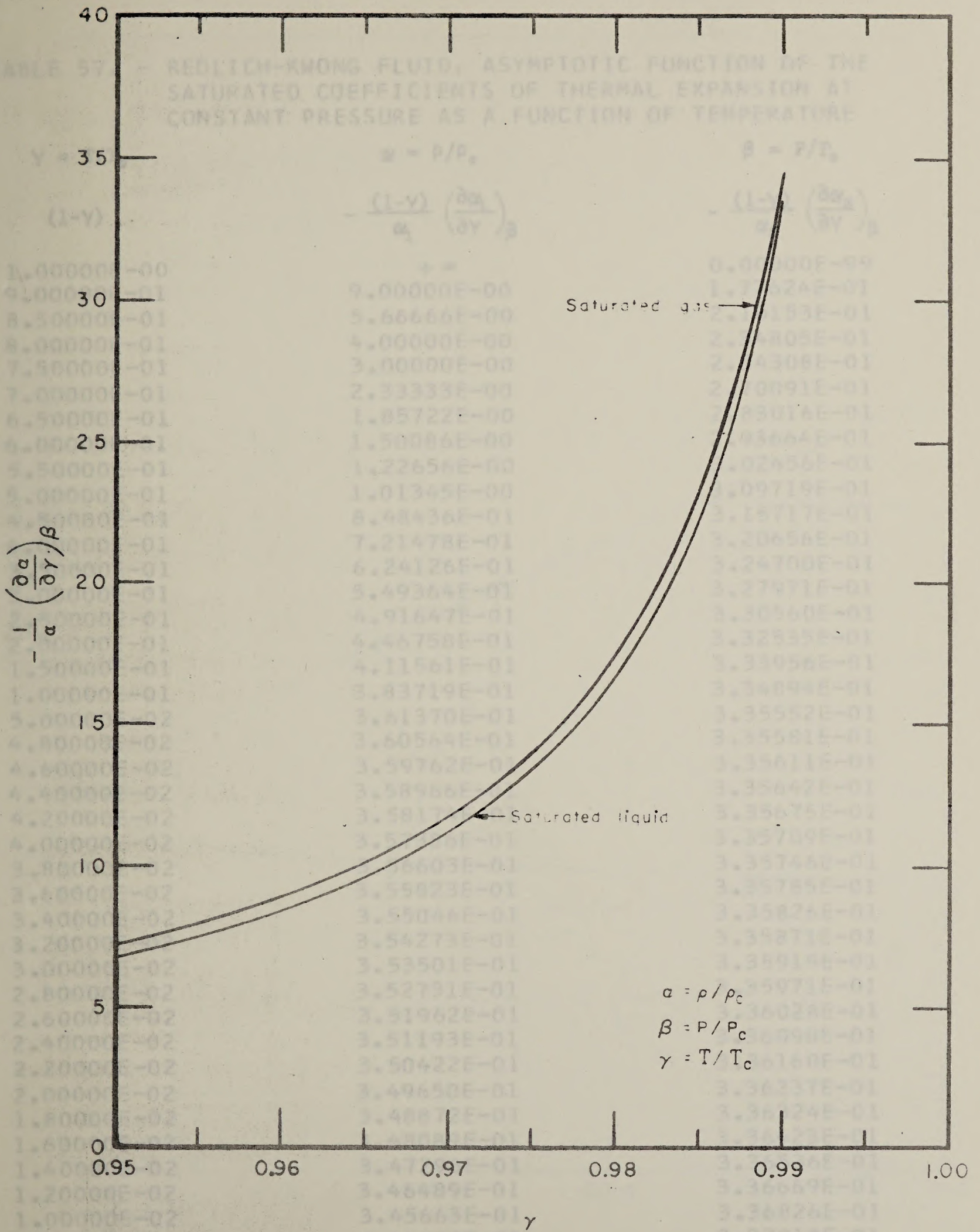


FIGURE 93.-Redlich-Kwong Fluid, Saturated Coefficients of Thermal Expansion at Constant Pressure as a Function of Temperature Near the Critical Point.

TABLE 57. - REDLICH-KWONG FLUID, ASYMPTOTIC FUNCTION OF THE SATURATED COEFFICIENTS OF THERMAL EXPANSION AT CONSTANT PRESSURE AS A FUNCTION OF TEMPERATURE

$\gamma = T/T_c$	$\alpha = \rho/\rho_c$	$\beta = P/P_c$
$(1-\gamma)$	$-\frac{(1-\gamma)}{\alpha_1} \left(\frac{\partial \alpha_1}{\partial \gamma} \right)_\beta$	$-\frac{(1-\gamma)}{\alpha_3} \left(\frac{\partial \alpha_3}{\partial \gamma} \right)_\beta$
1.00000E-00	$+\infty$	0.00000E-99
9.00000E-01	9.00000E-00	1.77624E-01
8.50000E-01	5.66666E-00	2.10153E-01
8.00000E-01	4.00000E-00	2.34805E-01
7.50000E-01	3.00000E-00	2.54308E-01
7.00000E-01	2.33333E-00	2.70091E-01
6.50000E-01	1.85722E-00	2.83016E-01
6.00000E-01	1.50086E-00	2.93664E-01
5.50000E-01	1.22656E-00	3.02456E-01
5.00000E-01	1.01345E-00	3.09719E-01
4.50000E-01	8.48436E-01	3.15717E-01
4.00000E-01	7.21478E-01	3.20656E-01
3.50000E-01	6.24126E-01	3.24700E-01
3.00000E-01	5.49364E-01	3.27971E-01
2.50000E-01	4.91647E-01	3.30560E-01
2.00000E-01	4.46758E-01	3.32535E-01
1.50000E-01	4.11561E-01	3.33956E-01
1.00000E-01	3.83719E-01	3.34894E-01
5.00000E-02	3.61370E-01	3.35552E-01
4.80000E-02	3.60564E-01	3.35581E-01
4.60000E-02	3.59762E-01	3.35611E-01
4.40000E-02	3.58966E-01	3.35642E-01
4.20000E-02	3.58174E-01	3.35675E-01
4.00000E-02	3.57386E-01	3.35709E-01
3.80000E-02	3.56603E-01	3.35746E-01
3.60000E-02	3.55823E-01	3.35785E-01
3.40000E-02	3.55046E-01	3.35826E-01
3.20000E-02	3.54273E-01	3.35871E-01
3.00000E-02	3.53501E-01	3.35919E-01
2.80000E-02	3.52731E-01	3.35971E-01
2.60000E-02	3.51962E-01	3.36028E-01
2.40000E-02	3.51193E-01	3.36090E-01
2.20000E-02	3.50422E-01	3.36160E-01
2.00000E-02	3.49650E-01	3.36237E-01
1.80000E-02	3.48872E-01	3.36324E-01
1.60000E-02	3.48089E-01	3.36423E-01
1.40000E-02	3.47296E-01	3.36536E-01
1.20000E-02	3.46489E-01	3.36669E-01
1.00000E-02	3.45663E-01	3.36826E-01
8.00000E-03	3.44807E-01	3.37018E-01
6.00000E-03	3.43907E-01	3.37259E-01
4.00000E-03	3.42931E-01	3.37582E-01
2.00000E-03	3.41795E-01	3.38069E-01
1.00000E-03	3.41078E-01	3.38463E-01
0.00000E-99	3.39610E-01	3.39610E-01

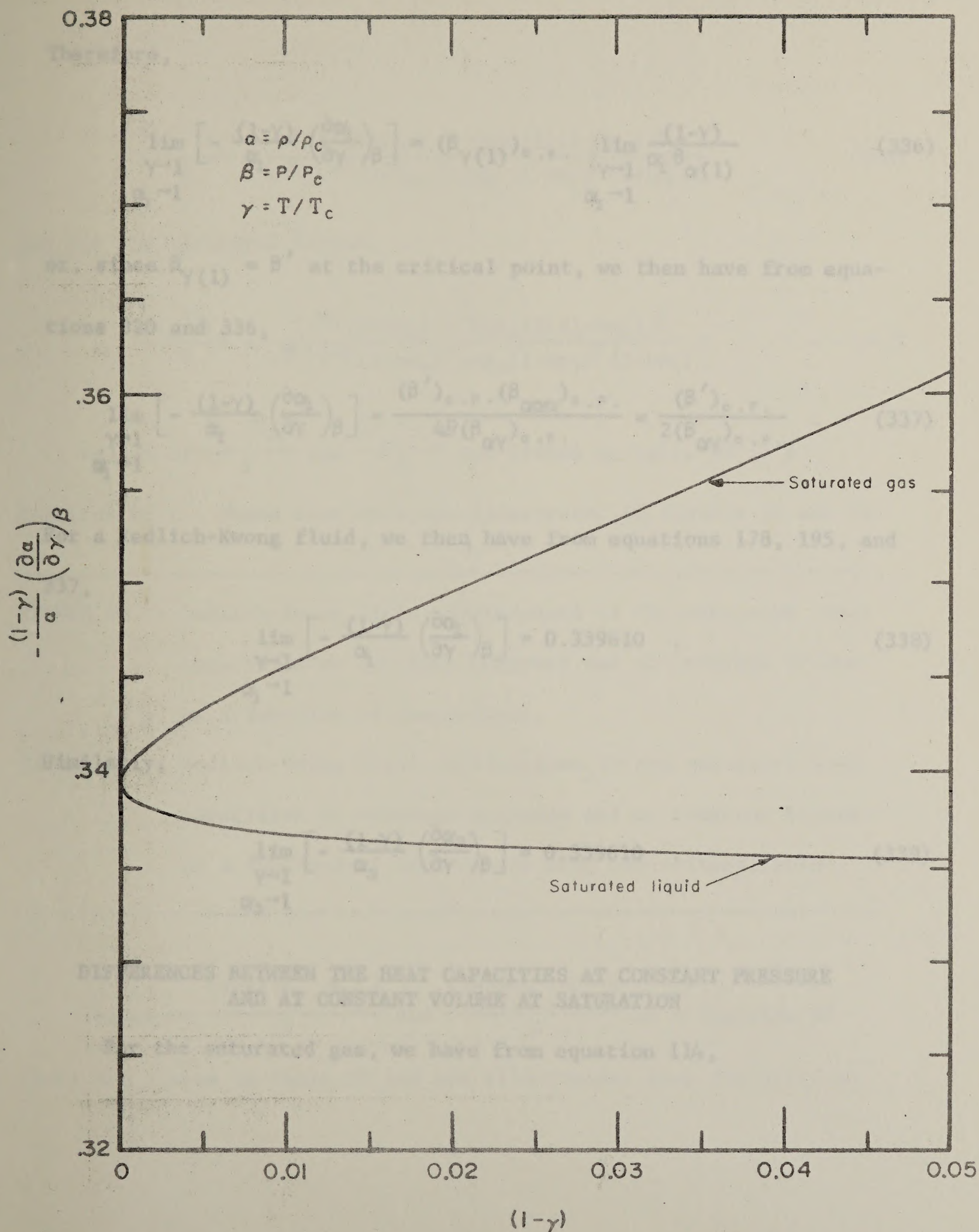


FIGURE 94.—Redlich-Kwong Fluid, Asymptotic Function of the Saturated Coefficients of Thermal Expansion at Constant Pressure as a Function of Temperature.

Therefore,

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha_1 \rightarrow 1}} \left[- \frac{(1-\gamma)}{\alpha_1} \left(\frac{\partial \alpha_1}{\partial \gamma} \right)_\beta \right] = (\beta_{\gamma(1)})_{c.p.} \lim_{\substack{\gamma \rightarrow 1 \\ \alpha_1 \rightarrow 1}} \frac{(1-\gamma)}{\alpha_1 \beta_{\alpha(1)}} \quad (336)$$

or, since $\beta_{\gamma(1)} = \beta'$ at the critical point, we then have from equations 320 and 336,

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha_1 \rightarrow 1}} \left[- \frac{(1-\gamma)}{\alpha_1} \left(\frac{\partial \alpha_1}{\partial \gamma} \right)_\beta \right] = \frac{(\beta')_{c.p.} (\beta_{\alpha\alpha\alpha})_{c.p.}}{4B(\beta_{\alpha\gamma})_{c.p.}} = \frac{(\beta')_{c.p.}}{2(\beta_{\alpha\gamma})_{c.p.}} \quad (337)$$

For a Redlich-Kwong fluid, we then have from equations 178, 195, and 337,

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha_1 \rightarrow 1}} \left[- \frac{(1-\gamma)}{\alpha_1} \left(\frac{\partial \alpha_1}{\partial \gamma} \right)_\beta \right] = 0.339610 \quad (338)$$

Similarly,

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha_3 \rightarrow 1}} \left[- \frac{(1-\gamma)}{\alpha_3} \left(\frac{\partial \alpha_3}{\partial \gamma} \right)_\beta \right] = 0.339610 \quad (339)$$

DIFFERENCES BETWEEN THE HEAT CAPACITIES AT CONSTANT PRESSURE AND AT CONSTANT VOLUME AT SATURATION

For the saturated gas, we have from equation 114,

TABLE 58. - REDLICH-KWONG FLUID, DIFFERENCES IN THE SATURATED HEAT CAPACITIES AT CONSTANT PRESSURE AND AT CONSTANT VOLUME AS A FUNCTION OF TEMPERATURE

$$\frac{C_{P_1} - C_{V_1}}{R} = \frac{[\gamma^{3/2} (1+b\alpha_1) + (a\alpha_1/2)(1-b\alpha_1)]^2}{\gamma^{3/2} [\gamma^{3/2} (1+b\alpha_1)^2 - a\alpha_1 (1-b\alpha_1)^2 (2+b\alpha_1)]} \quad (340)$$

and for the saturated liquid,

$$\frac{C_{P_3} - C_{V_3}}{R} = \frac{[\gamma^{3/2} (1+b\alpha_3) + (a\alpha_3/2)(1-b\alpha_3)]^2}{\gamma^{3/2} [\gamma^{3/2} (1+b\alpha_3)^2 - a\alpha_3 (1-b\alpha_3)^2 (2+b\alpha_3)]} \quad (341)$$

Values of $\frac{C_{P_1} - C_{V_1}}{R}$ and $\frac{C_{P_3} - C_{V_3}}{R}$ are listed in table 58 as a function of γ . These same data are illustrated in figures 95 and 96.

FIGURE 95. - Redlich-Kwong fluid, differences in the saturated heat capacities at constant pressure and at constant volume as a function of temperature.

FIGURE 96. - Redlich-Kwong fluid, differences in the saturated heat capacities at constant pressure and at constant volume as a function of temperature near the critical point.

Values of $\frac{(1-\gamma)(C_{P_1} - C_{V_1})}{R}$ and $\frac{(1-\gamma)(C_{P_3} - C_{V_3})}{R}$ as a function of $(1-\gamma)$ are listed in table 59 and are illustrated, near the critical

TABLE 58. - REDLICH-KWONG FLUID, DIFFERENCES IN THE SATURATED HEAT CAPACITIES AT CONSTANT PRESSURE AND AT CONSTANT VOLUME AS A FUNCTION OF TEMPERATURE

γ	$\gamma = T/T_c$	$C_{p1} - C_{v1}$	$C_{p3} - C_{v3}$
		$\frac{\quad}{R}$	$\frac{\quad}{R}$
0.00000E-99		1.00000E+00	2.25000E+00
1.00000E-01		1.00000E-00	2.29450E-00
1.50000E-01		1.00000E-00	2.33377E-00
2.00000E-01		1.00000E-00	2.38290E-00
2.50000E-01		1.00000E-00	2.44243E-00
3.00000E-01		1.00000E-00	2.51355E-00
3.50000E-01		1.00005E-00	2.59814E-00
4.00000E-01		1.00070E-00	2.69894E-00
4.50000E-01		1.00437E-00	2.81984E-00
5.00000E-01		1.01663E-00	2.96642E-00
5.50000E-01		1.04597E-00	3.14679E-00
6.00000E-01		1.10296E-00	3.37299E-00
6.50000E-01		1.20108E-00	3.66372E-00
7.00000E-01		1.36045E-00	4.04972E-00
7.50000E-01		1.61666E-00	4.58554E-00
8.00000E-01		2.04217E-00	5.37864E-00
8.50000E-01		2.81091E-00	6.67556E-00
9.00000E-01		4.46069E-00	9.20124E-00
9.50000E-01		9.77862E-00	1.64852E+01
9.52000E-01		1.02353E+01	1.70801E+01
9.54000E-01		1.07333E+01	1.77253E+01
9.56000E-01		1.12783E+01	1.84275E+01
9.58000E-01		1.18773E+01	1.91946E+01
9.60000E-01		1.25385E+01	2.00364E+01
9.62000E-01		1.32717E+01	2.09644E+01
9.64000E-01		1.40894E+01	2.19927E+01
9.66000E-01		1.50065E+01	2.31388E+01
9.68000E-01		1.60421E+01	2.44245E+01
9.70000E-01		1.72202E+01	2.58774E+01
9.72000E-01		1.85718E+01	2.75328E+01
9.74000E-01		2.01377E+01	2.94367E+01
9.76000E-01		2.19721E+01	3.16506E+01
9.78000E-01		2.41493E+01	3.42580E+01
9.80000E-01		2.67737E+01	3.73755E+01
9.82000E-01		2.99961E+01	4.11711E+01
9.84000E-01		3.40437E+01	4.58963E+01
9.86000E-01		3.92745E+01	5.19451E+01
9.88000E-01		4.62870E+01	5.99725E+01
9.90000E-01		5.61623E+01	7.11536E+01
9.92000E-01		7.10703E+01	8.78306E+01
9.94000E-01		9.60955E+01	1.15448E+02
9.96000E-01		1.46564E+02	1.70265E+02
9.98000E-01		2.99586E+02	3.33104E+02
9.99000E-01		6.08507E+02	6.55907E+02
1.00000E-00		+ ∞	+ ∞

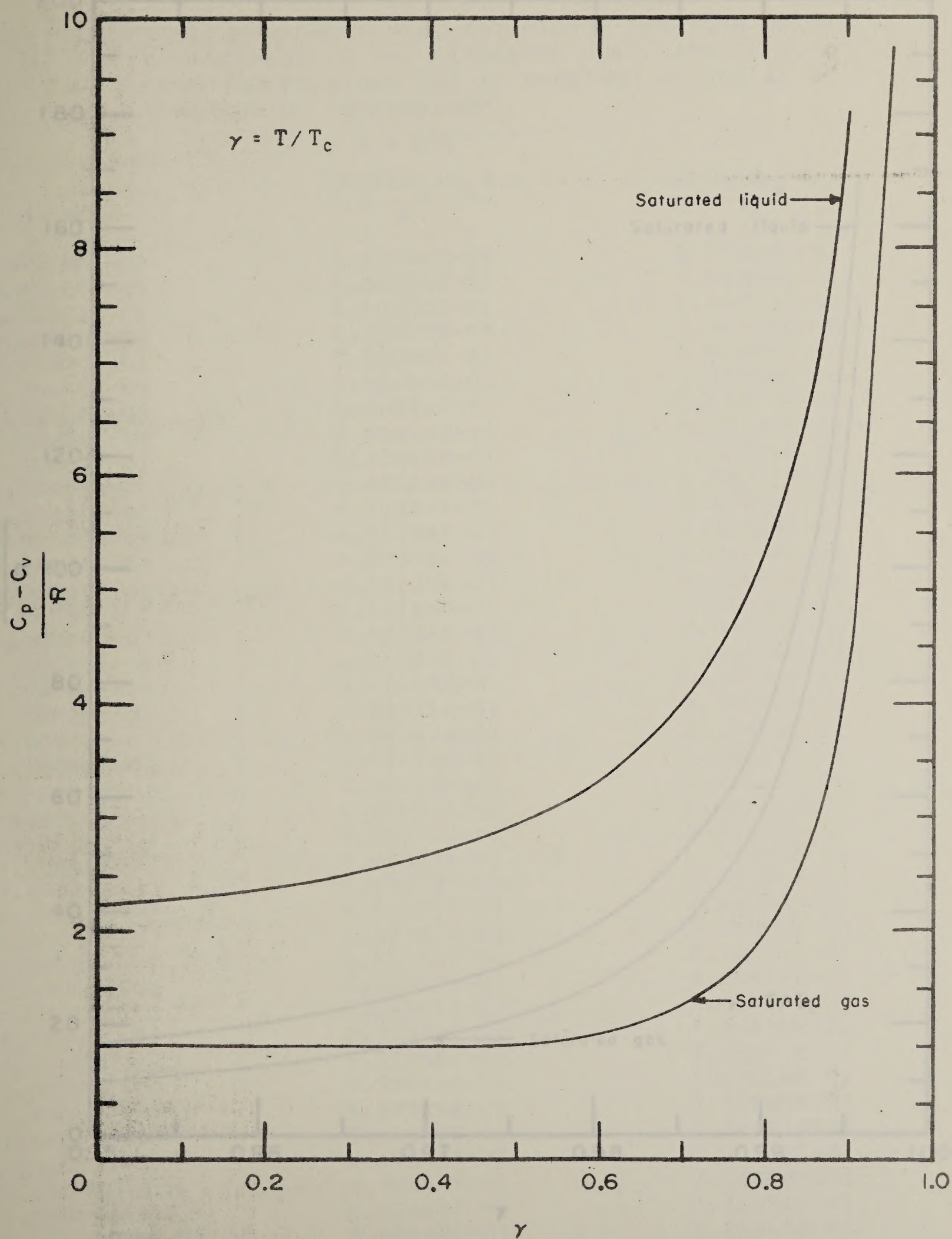


FIGURE 95.—Redlich-Kwong Fluid, Differences in the Saturated Heat Capacities at Constant Pressure and at Constant Volume as a Function of Temperature.

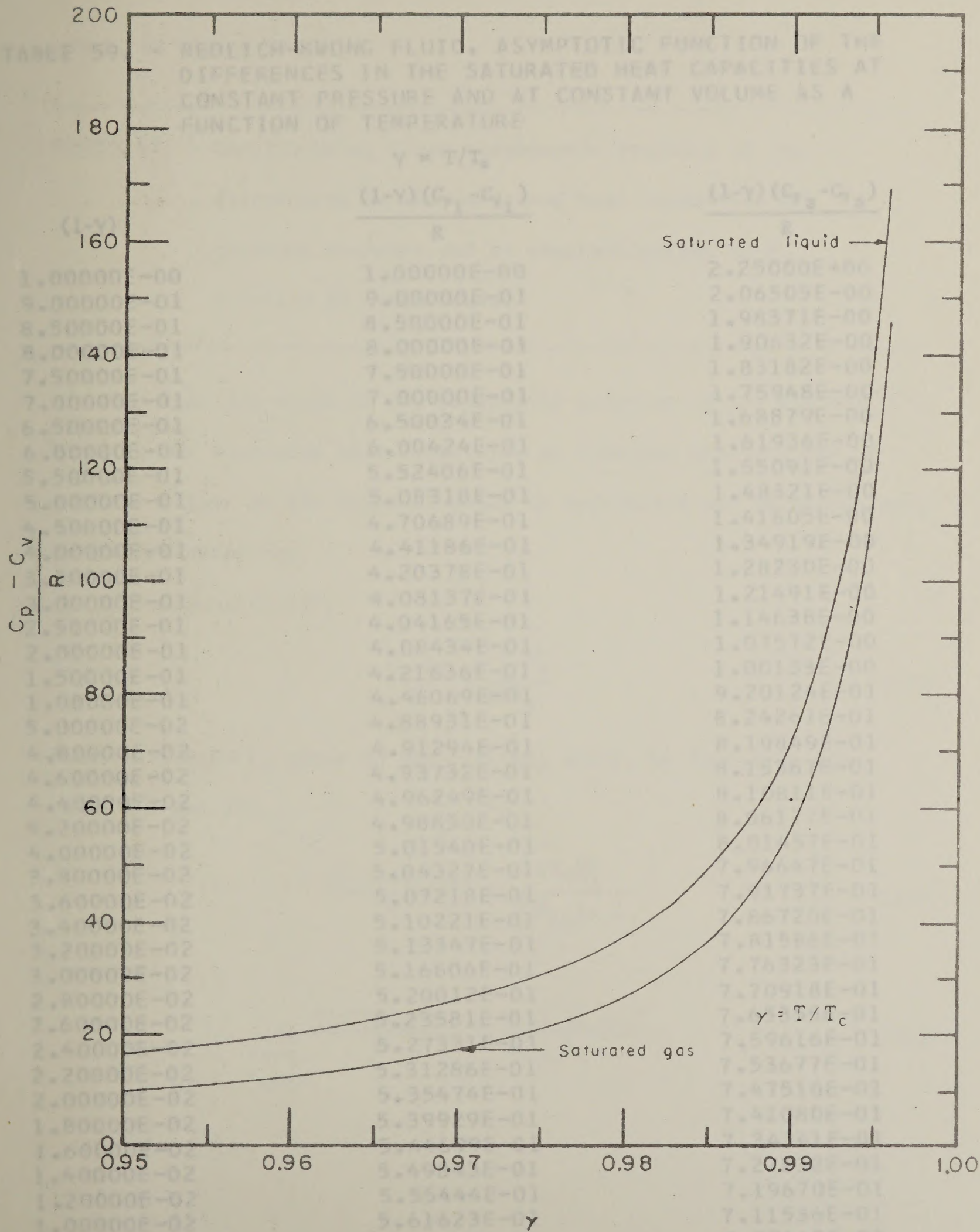


FIGURE 96.—Redlich - Kwong Fluid, Differences in the Saturated Heat Capacities at Constant Pressure and at Constant Volume as a Function of Temperature Near the Critical Point.

TABLE 59. - REDLICH-KWONG FLUID, ASYMPTOTIC FUNCTION OF THE DIFFERENCES IN THE SATURATED HEAT CAPACITIES AT CONSTANT PRESSURE AND AT CONSTANT VOLUME AS A FUNCTION OF TEMPERATURE

(1- γ)	$\gamma = T/T_c$	
	$(1-\gamma) (C_{p_1} - C_{v_1})$ R	$(1-\gamma) (C_{p_3} - C_{v_3})$ R
1.00000E-00	1.00000E-00	2.25000E+00
9.00000E-01	9.00000E-01	2.06505E-00
8.50000E-01	8.50000E-01	1.98371E-00
8.00000E-01	8.00000E-01	1.90632E-00
7.50000E-01	7.50000E-01	1.83182E-00
7.00000E-01	7.00000E-01	1.75948E-00
6.50000E-01	6.50034E-01	1.68879E-00
6.00000E-01	6.00424E-01	1.61936E-00
5.50000E-01	5.52406E-01	1.55091E-00
5.00000E-01	5.08318E-01	1.48321E-00
4.50000E-01	4.70689E-01	1.41605E-00
4.00000E-01	4.41186E-01	1.34919E-00
3.50000E-01	4.20378E-01	1.28230E-00
3.00000E-01	4.08137E-01	1.21491E-00
2.50000E-01	4.04165E-01	1.14638E-00
2.00000E-01	4.08434E-01	1.07572E-00
1.50000E-01	4.21636E-01	1.00133E-00
1.00000E-01	4.46069E-01	9.20124E-01
5.00000E-02	4.88931E-01	8.24261E-01
4.80000E-02	4.91294E-01	8.19849E-01
4.60000E-02	4.93732E-01	8.15367E-01
4.40000E-02	4.96249E-01	8.10811E-01
4.20000E-02	4.98850E-01	8.06177E-01
4.00000E-02	5.01540E-01	8.01457E-01
3.80000E-02	5.04327E-01	7.96647E-01
3.60000E-02	5.07218E-01	7.91737E-01
3.40000E-02	5.10221E-01	7.86720E-01
3.20000E-02	5.13347E-01	7.81586E-01
3.00000E-02	5.16606E-01	7.76323E-01
2.80000E-02	5.20012E-01	7.70918E-01
2.60000E-02	5.23581E-01	7.65355E-01
2.40000E-02	5.27331E-01	7.59616E-01
2.20000E-02	5.31286E-01	7.53677E-01
2.00000E-02	5.35474E-01	7.47510E-01
1.80000E-02	5.39929E-01	7.41080E-01
1.60000E-02	5.44699E-01	7.34341E-01
1.40000E-02	5.49843E-01	7.27232E-01
1.20000E-02	5.55444E-01	7.19670E-01
1.00000E-02	5.61623E-01	7.11536E-01
8.00000E-03	5.68562E-01	7.02645E-01
6.00000E-03	5.76573E-01	6.92688E-01
4.00000E-03	5.86257E-01	6.81062E-01
2.00000E-03	5.99173E-01	6.66208E-01
1.00000E-03	6.08507E-01	6.55907E-01
0.00000E-99	6.31724E-01	6.31724E-01

point, in figure 97.

FIGURE 97. - Redlich-Kwong fluid, asymptotic function of the differences in the saturated heat capacities at constant pressure and at constant volume as a function of temperature.

The limiting value of the asymptotic function of the differences in the saturated heat capacities at constant pressure and at constant volume as the critical point is approached may be determined in the following way.

From equation 113,

$$\frac{C_p - C_v}{R} = \frac{\gamma Z_c \beta_Y^2}{\alpha^2 \beta_\alpha} \quad (113)$$

Then, sufficiently close to the critical point, we have from equations 113 and 260,

$$\frac{(1-\gamma)(C_p - C_v)}{R} = \frac{\gamma Z_c \beta_Y^2}{2(\beta_{\alpha\gamma})_{c.p.}} \quad (342)$$

Therefore,

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha \rightarrow 1}} \frac{(1-\gamma)(C_p - C_v)}{R} = \frac{Z_c (\beta')_{c.p.}^2}{2(\beta_{\alpha\gamma})_{c.p.}} \quad (343)$$

FIGURE 97. - Redlich-Kwong Fluid, Asymptotic Function of the Differences in the Saturated Heat Capacities at Constant Pressure and at Constant Volume as a Function of Temperature.

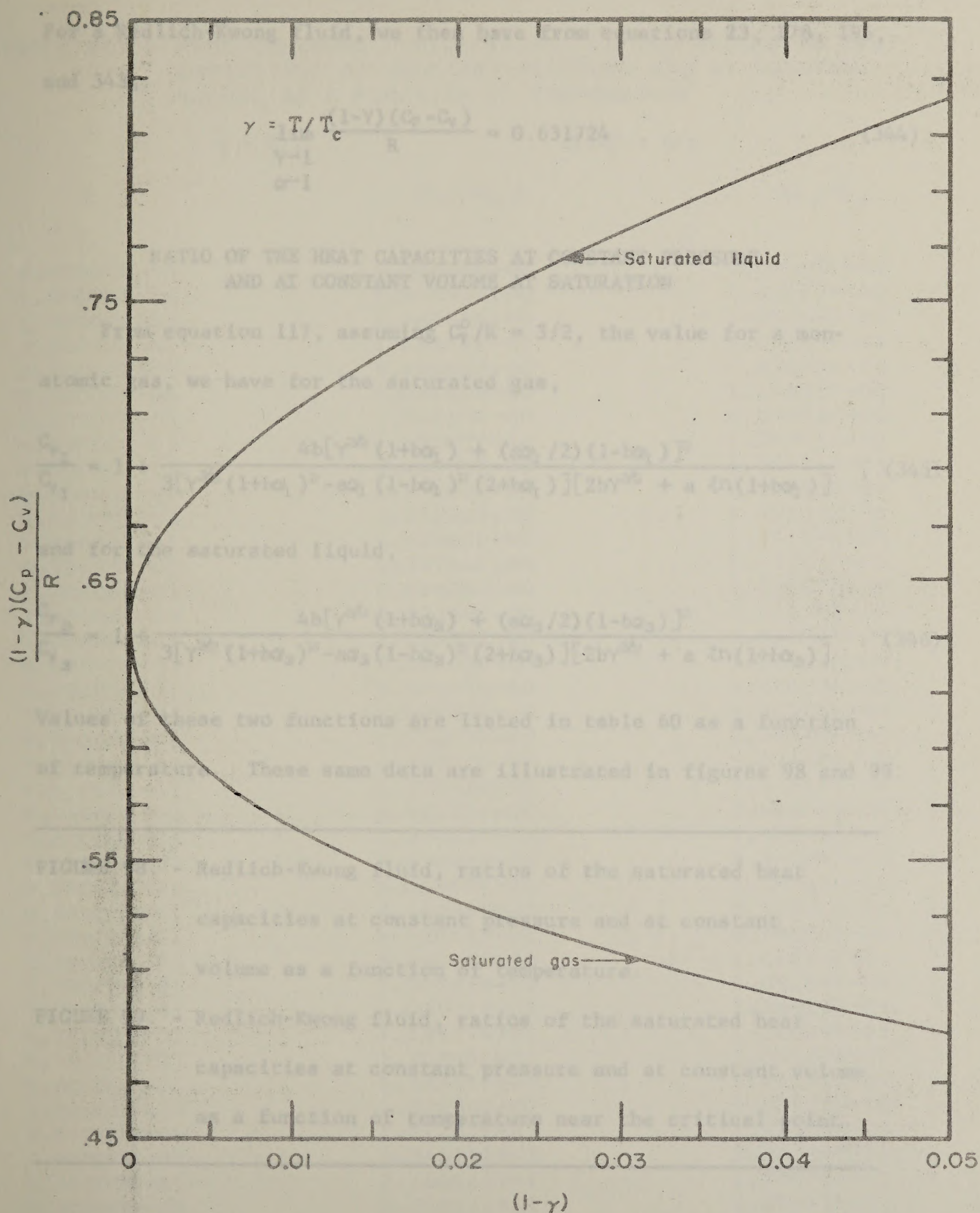


FIGURE 97.-Redlich-Kwong Fluid, Asymptotic Function of the Differences in the Saturated Heat Capacities at Constant Pressure and at Constant Volume as a Function of Temperature.

For a Redlich-Kwong fluid, we then have from equations 23, 178, 195, and 343,

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha \rightarrow 1}} \frac{(1-\gamma)(C_p - C_v)}{R} = 0.631724 \quad (344)$$

RATIO OF THE HEAT CAPACITIES AT CONSTANT PRESSURE AND AT CONSTANT VOLUME AT SATURATION

From equation 117, assuming $C_v^0/R = 3/2$, the value for a monatomic gas, we have for the saturated gas,

$$\frac{C_{p_1}}{C_{v_1}} = 1 + \frac{4b[\gamma^{3/2}(1+b\alpha_1) + (a\alpha_1/2)(1-b\alpha_1)]^2}{3[\gamma^{3/2}(1+b\alpha_1)^2 - a\alpha_1(1-b\alpha_1)^2(2+b\alpha_1)][2b\gamma^{3/2} + a \ln(1+b\alpha_1)]} \quad (345)$$

and for the saturated liquid,

$$\frac{C_{p_3}}{C_{v_3}} = 1 + \frac{4b[\gamma^{3/2}(1+b\alpha_3) + (a\alpha_3/2)(1-b\alpha_3)]^2}{3[\gamma^{3/2}(1+b\alpha_3)^2 - a\alpha_3(1-b\alpha_3)^2(2+b\alpha_3)][2b\gamma^{3/2} + a \ln(1+b\alpha_3)]} \quad (346)$$

Values of these two functions are listed in table 60 as a function of temperature. These same data are illustrated in figures 98 and 99.

FIGURE 98. - Redlich-Kwong fluid, ratios of the saturated heat capacities at constant pressure and at constant volume as a function of temperature.

FIGURE 99. - Redlich-Kwong fluid, ratios of the saturated heat capacities at constant pressure and at constant volume as a function of temperature near the critical point.

TABLE 60. - REDLICH-KWONG FLUID, RATIOS OF THE SATURATED HEAT CAPACITIES AT CONSTANT PRESSURE AND AT CONSTANT VOLUME AS A FUNCTION OF TEMPERATURE

$$\gamma = T/T_c$$

$$C_p^0/C_v^0 = 5/3$$

γ	(C_{p_1}/C_{v_1})	(C_{p_3}/C_{v_3})
0.00000E-99	1.66666E+00	1.00000E+00
1.00000E-01	1.66666E-00	1.02803E-00
1.50000E-01	1.66666E-00	1.05199E-00
2.00000E-01	1.66666E-00	1.08103E-00
2.50000E-01	1.66666E-00	1.11499E-00
3.00000E-01	1.66666E-00	1.15403E-00
3.50000E-01	1.66669E-00	1.19858E-00
4.00000E-01	1.66705E-00	1.24942E-00
4.50000E-01	1.66909E-00	1.30776E-00
5.00000E-01	1.67590E-00	1.37543E-00
5.50000E-01	1.69216E-00	1.45518E-00
6.00000E-01	1.72363E-00	1.55127E-00
6.50000E-01	1.77746E-00	1.67041E-00
7.00000E-01	1.86409E-00	1.82387E-00
7.50000E-01	2.00149E-00	2.03188E-00
8.00000E-01	2.22567E-00	2.33471E-00
8.50000E-01	2.62153E-00	2.82588E-00
9.00000E-01	3.44647E-00	3.78407E-00
9.50000E-01	6.00084E-00	6.59106E-00
9.52000E-01	6.21604E-00	6.82283E-00
9.54000E-01	6.45020E-00	7.07452E-00
9.56000E-01	6.70592E-00	7.34883E-00
9.58000E-01	6.98628E-00	7.64897E-00
9.60000E-01	7.29501E-00	7.97882E-00
9.62000E-01	7.63661E-00	8.34304E-00
9.64000E-01	8.01657E-00	8.74733E-00
9.66000E-01	8.44169E-00	9.19874E-00
9.68000E-01	8.92047E-00	9.70606E-00
9.70000E-01	9.46369E-00	1.02804E+01
9.72000E-01	1.00852E+01	1.09362E+01
9.74000E-01	1.08031E+01	1.16920E+01
9.76000E-01	1.16417E+01	1.25729E+01
9.78000E-01	1.26340E+01	1.36127E+01
9.80000E-01	1.38261E+01	1.48591E+01
9.82000E-01	1.52850E+01	1.63807E+01
9.84000E-01	1.71109E+01	1.82803E+01
9.86000E-01	1.94618E+01	2.07196E+01
9.88000E-01	2.26006E+01	2.39675E+01
9.90000E-01	2.70017E+01	2.85081E+01
9.92000E-01	3.36139E+01	3.53082E+01
9.94000E-01	4.46541E+01	4.66221E+01
9.96000E-01	6.67800E+01	6.92044E+01
9.98000E-01	1.33330E+02	1.36778E+02
9.99000E-01	2.66733E+02	2.71624E+02
1.00000E-00	+ ∞	+ ∞

Monatomic gas, $C_p^0/C_v^0 = 5/3$
 $\gamma = T/T_c$

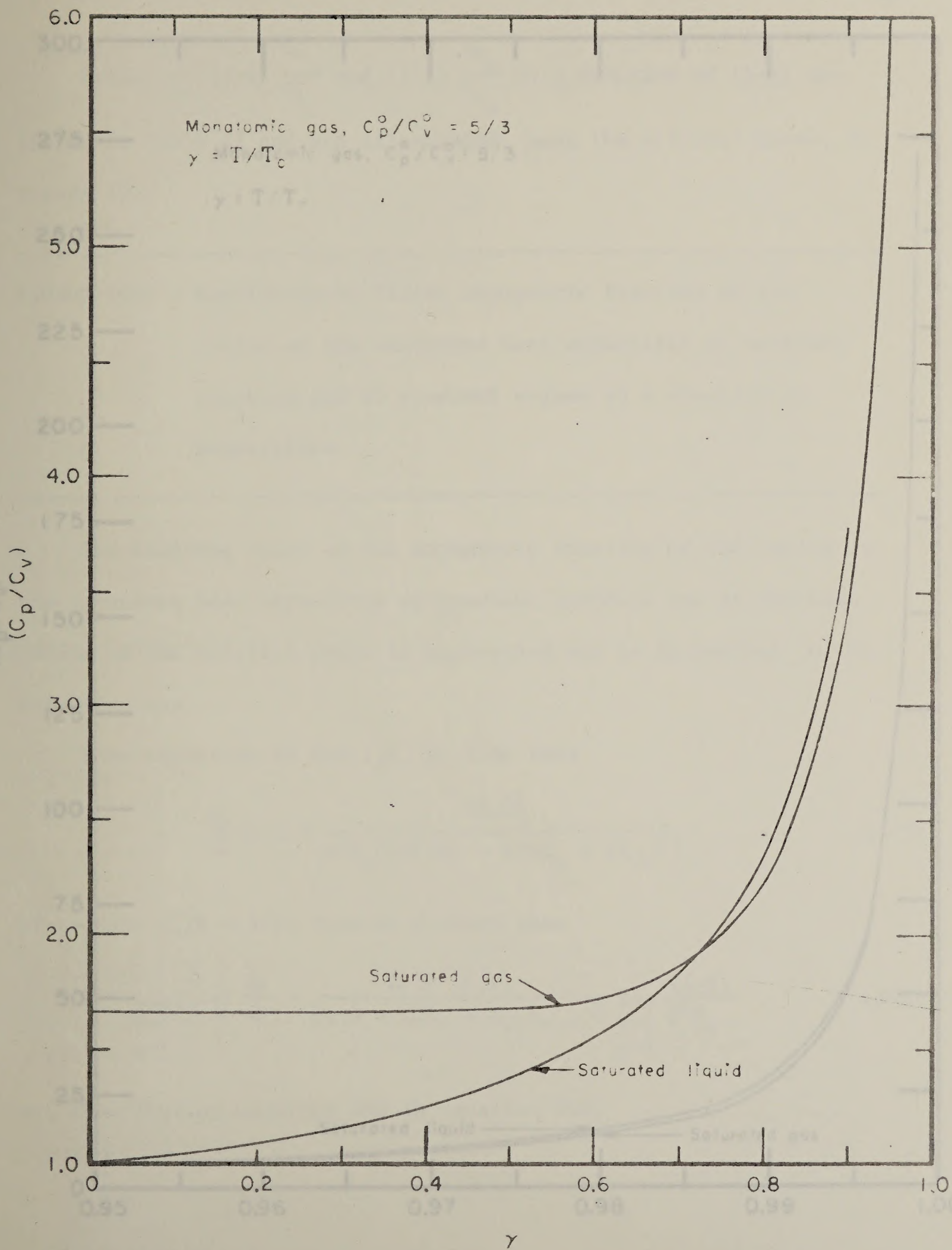


FIGURE 98.—Redlich-Kwong Fluid, Ratios of the Saturated Heat Capacities at Constant Pressure and at Constant Volume as a Function of Temperature.

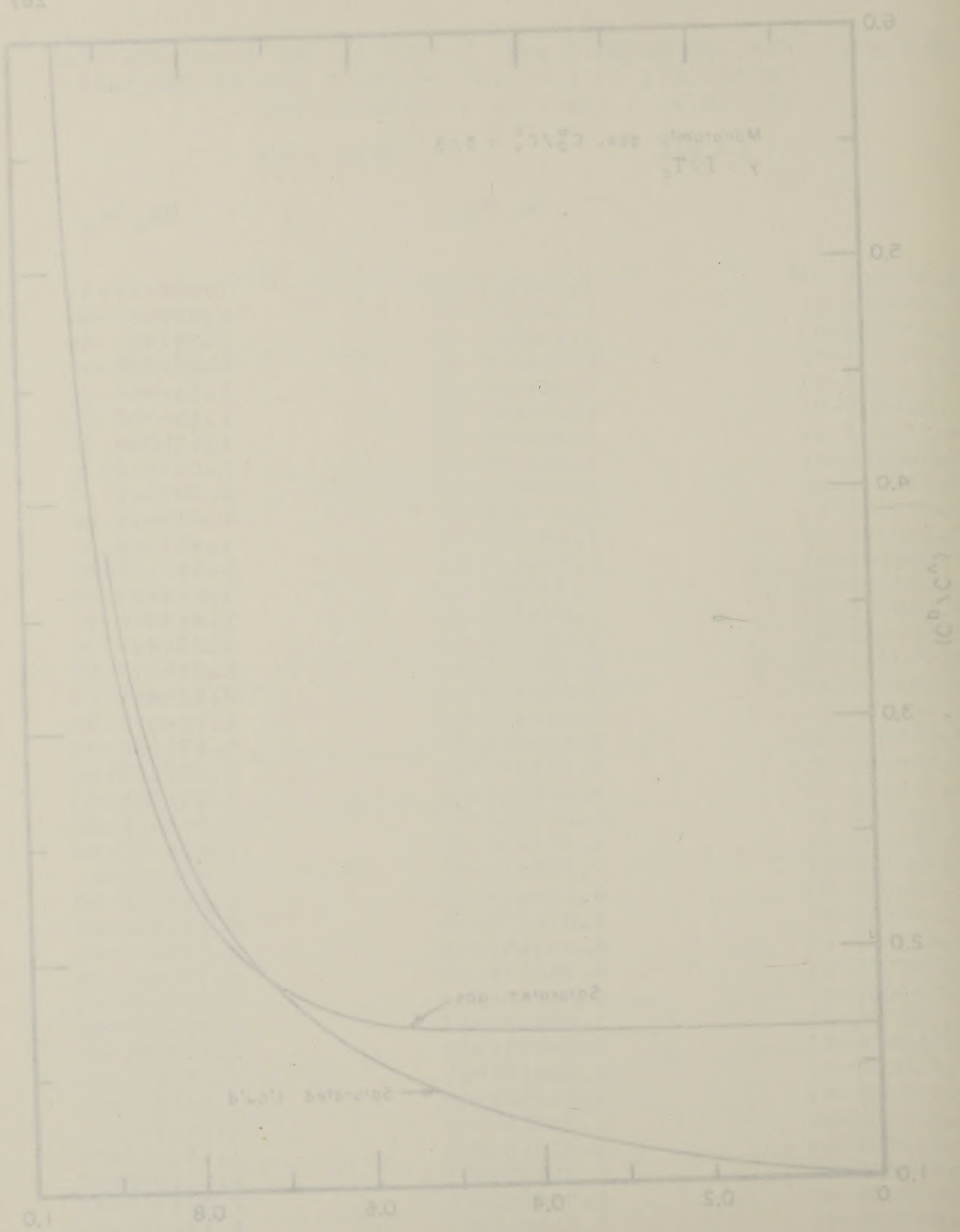


FIGURE 98-Redlich-Kwong Fluid, Ratios of the Saturated Heat Capacities at Constant Pressure and at Constant Volume as a Function of Temperature.

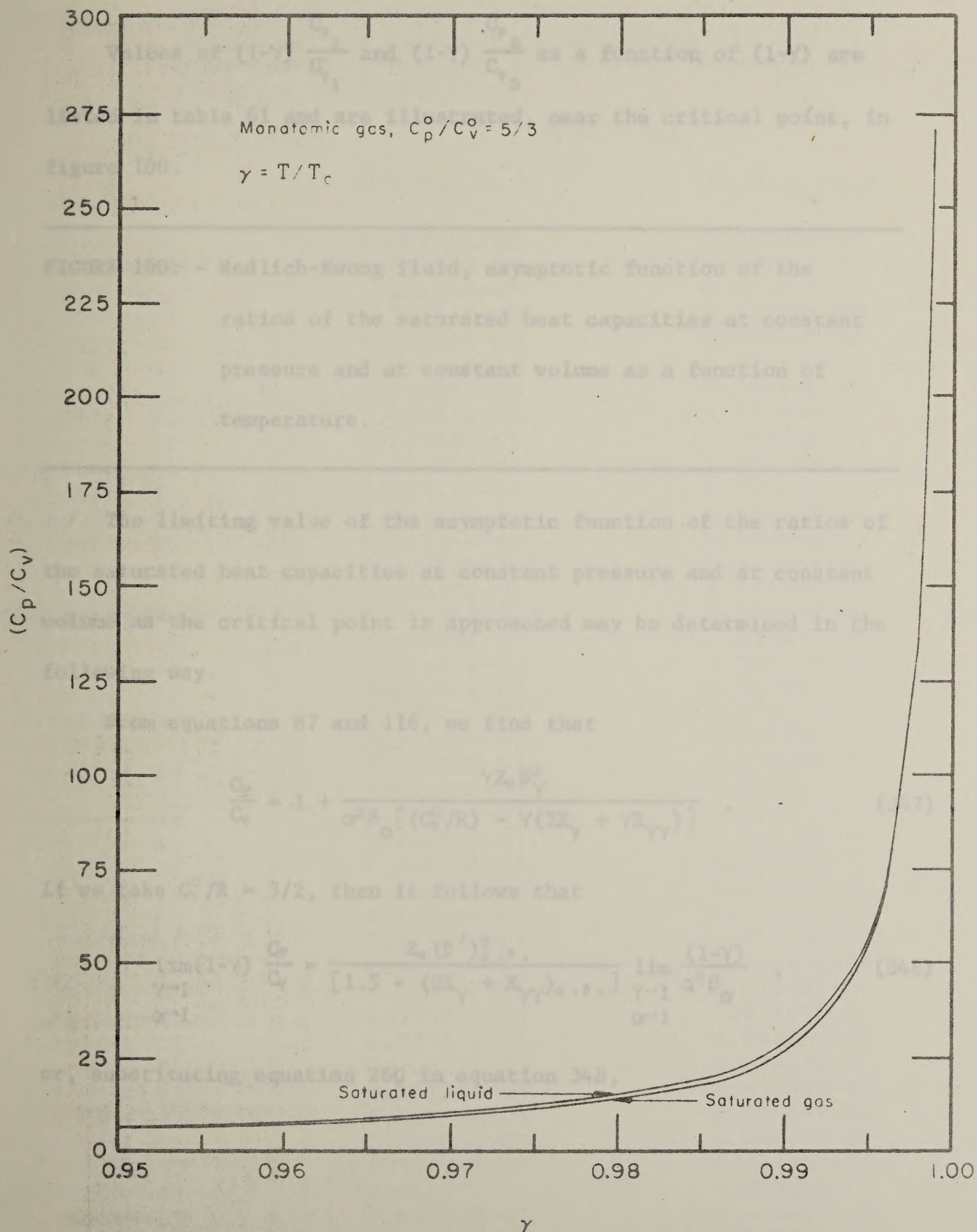


FIGURE 99.-Redlich-Kwong Fluid, Ratios of the Saturated Heat Capacities at Constant Pressure and at Constant Volume as a Function of Temperature Near the Critical Point.

Values of $(1-\gamma) \frac{C_{p1}}{C_{v1}}$ and $(1-\gamma) \frac{C_{p3}}{C_{v3}}$ as a function of $(1-\gamma)$ are

listed in table 61 and are illustrated, near the critical point, in figure 100.

FIGURE 100. - Redlich-Kwong fluid, asymptotic function of the ratios of the saturated heat capacities at constant pressure and at constant volume as a function of temperature.

The limiting value of the asymptotic function of the ratios of the saturated heat capacities at constant pressure and at constant volume as the critical point is approached may be determined in the following way.

From equations 87 and 116, we find that

$$\frac{C_p}{C_v} = 1 + \frac{\gamma Z_c \beta_\gamma^2}{\alpha^2 \beta_\alpha [(C_v^0/R) - \gamma(2X_Y + \gamma X_{YY})]} \quad (347)$$

If we take $C_v^0/R = 3/2$, then it follows that

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha \rightarrow 1}} (1-\gamma) \frac{C_p}{C_v} = \frac{Z_c (\beta'_c)^2_{c.p.}}{[1.5 - (2X_Y + X_{YY})_{c.p.}]} \lim_{\substack{\gamma \rightarrow 1 \\ \alpha \rightarrow 1}} \frac{(1-\gamma)}{\alpha^2 \beta_\alpha}, \quad (348)$$

or, substituting equation 260 in equation 348,

TABLE 61. - REDLICH-KWONG FLUID, ASYMPTOTIC FUNCTION OF THE RATIOS OF THE SATURATED HEAT CAPACITIES AT CONSTANT PRESSURE AND AT CONSTANT VOLUME AS A FUNCTION OF TEMPERATURE

$$\gamma = T/T_c$$

$$C_p^0/C_v^0 = 5/3$$

(1- γ)	(1- γ) (C_{p_1}/C_{v_1})	(1- γ) (C_{p_3}/C_{v_3})
1.00000E-00	1.66666E+00	1.00000E-00
9.00000E-01	1.49999E-00	9.25228E-01
8.50000E-01	1.41666E-00	8.94192E-01
8.00000E-01	1.33333E-00	8.64828E-01
7.50000E-01	1.25000E-00	8.36248E-01
7.00000E-01	1.16666E-00	8.07822E-01
6.50000E-01	1.08335E-00	7.79078E-01
6.00000E-01	1.00023E-00	7.49654E-01
5.50000E-01	9.18003E-01	7.19270E-01
5.00000E-01	8.37951E-01	6.87715E-01
4.50000E-01	7.61473E-01	6.54833E-01
4.00000E-01	6.89452E-01	6.20508E-01
3.50000E-01	6.22114E-01	5.84645E-01
3.00000E-01	5.59228E-01	5.47163E-01
2.50000E-01	5.00373E-01	5.07970E-01
2.00000E-01	4.45134E-01	4.66942E-01
1.50000E-01	3.93229E-01	4.23882E-01
1.00000E-01	3.44647E-01	3.78407E-01
5.00000E-02	3.00042E-01	3.29553E-01
4.80000E-02	2.98370E-01	3.27496E-01
4.60000E-02	2.96709E-01	3.25428E-01
4.40000E-02	2.95060E-01	3.23348E-01
4.20000E-02	2.93424E-01	3.21257E-01
4.00000E-02	2.91800E-01	3.19153E-01
3.80000E-02	2.90191E-01	3.17035E-01
3.60000E-02	2.88596E-01	3.14904E-01
3.40000E-02	2.87017E-01	3.12757E-01
3.20000E-02	2.85455E-01	3.10594E-01
3.00000E-02	2.83910E-01	3.08413E-01
2.80000E-02	2.82386E-01	3.06213E-01
2.60000E-02	2.80882E-01	3.03993E-01
2.40000E-02	2.79402E-01	3.01749E-01
2.20000E-02	2.77948E-01	2.99480E-01
2.00000E-02	2.76523E-01	2.97183E-01
1.80000E-02	2.75130E-01	2.94853E-01
1.60000E-02	2.73775E-01	2.92486E-01
1.40000E-02	2.72465E-01	2.90075E-01
1.20000E-02	2.71208E-01	2.87610E-01
1.00000E-02	2.70017E-01	2.85081E-01
8.00000E-03	2.68911E-01	2.82465E-01
6.00000E-03	2.67924E-01	2.79732E-01
4.00000E-03	2.67120E-01	2.76817E-01
2.00000E-03	2.66660E-01	2.73557E-01
1.00000E-03	2.66733E-01	2.71624E-01
0.00000E-99	2.68249E-01	2.68249E-01

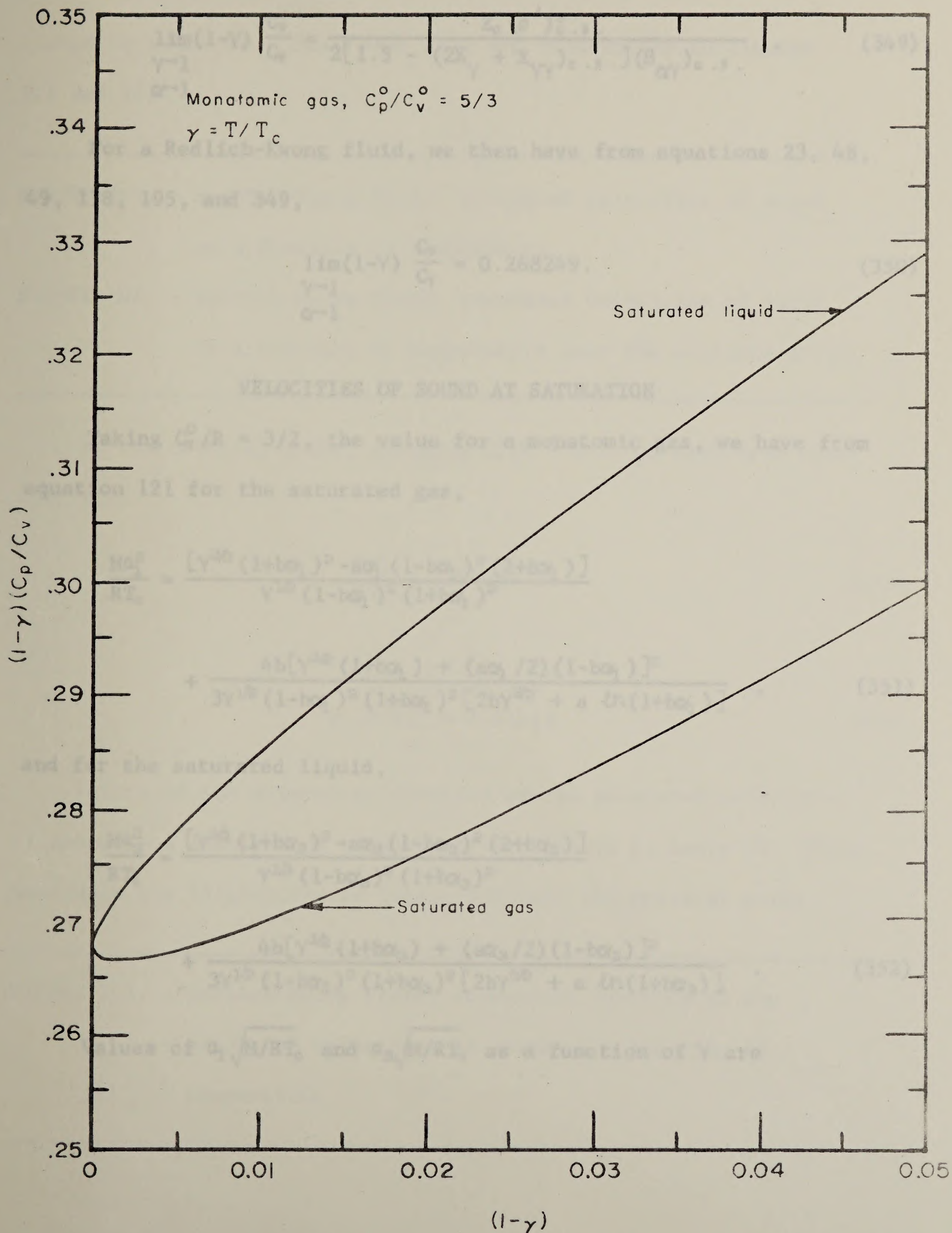


FIGURE 100.—Redlich-Kwong Fluid, Asymptotic Function of the Ratios of the Saturated Heat Capacities at Constant Pressure and at Constant Volume as a Function of Temperature.

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha \rightarrow 1}} (1-\gamma) \frac{C_p}{C_v} = \frac{Z_c (\beta')_{c.p.}^2}{2[1.5 - (2X_\gamma + X_{\gamma\gamma})_{c.p.}] (\beta_{\alpha\gamma})_{c.p.}} \quad (349)$$

For a Redlich-Kwong fluid, we then have from equations 23, 48, 49, 178, 195, and 349,

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha \rightarrow 1}} (1-\gamma) \frac{C_p}{C_v} = 0.268249. \quad (350)$$

VELOCITIES OF SOUND AT SATURATION

Taking $C_v^0/R = 3/2$, the value for a monatomic gas, we have from equation 121 for the saturated gas,

$$\begin{aligned} \frac{Ma_1^2}{RT_c} &= \frac{[\gamma^{3/2} (1+b\alpha_1)^2 - a\alpha_1 (1-b\alpha_1)^2 (2+b\alpha_1)]}{\gamma^{1/2} (1-b\alpha_1)^2 (1+b\alpha_1)^2} \\ &+ \frac{4b[\gamma^{3/2} (1+b\alpha_1) + (a\alpha_1/2)(1-b\alpha_1)]^2}{3\gamma^{1/2} (1-b\alpha_1)^2 (1+b\alpha_1)^2 [2b\gamma^{3/2} + a \ln(1+b\alpha_1)]} \quad (351) \end{aligned}$$

and for the saturated liquid,

$$\begin{aligned} \frac{Ma_3^2}{RT_c} &= \frac{[\gamma^{3/2} (1+b\alpha_3)^2 - a\alpha_3 (1-b\alpha_3)^2 (2+b\alpha_3)]}{\gamma^{1/2} (1-b\alpha_3)^2 (1+b\alpha_3)^2} \\ &+ \frac{4b[\gamma^{3/2} (1+b\alpha_3) + (a\alpha_3/2)(1-b\alpha_3)]^2}{3\gamma^{1/2} (1-b\alpha_3)^2 (1+b\alpha_3)^2 [2b\gamma^{3/2} + a \ln(1+b\alpha_3)]} \quad (352) \end{aligned}$$

Values of $\alpha_1 \sqrt{M/RT_c}$ and $\alpha_3 \sqrt{M/RT_c}$ as a function of γ are

listed in table 62. These same data are illustrated in figures 101 and 102.

FIGURE 101. - Redlich-Kwong fluid, saturated velocities of sound as a function of temperature.

FIGURE 102. - Redlich-Kwong fluid, saturated velocities of sound as a function of temperature near the critical point.

At the critical point, assuming $C_v^0/R = 3/2$, we have from equation 122,

$$\frac{Ma_c^2}{RT_c} = 1.46927 \quad (353)$$

or,

$$\alpha_c \sqrt{M/RT_c} = 1.21213 \quad (354)$$

Values of the asymptotic function of the saturated velocities of sound as a function of temperature are listed in table 63. These same data are illustrated in figure 103 near the critical point.

FIGURE 103. - Redlich-Kwong fluid, asymptotic function of the saturated velocities of sound as a function of temperature.

TABLE 62. - REDLICH-KWONG FLUID, SATURATED VELOCITIES OF SOUND AS A FUNCTION OF TEMPERATURE

 a = velocity M = molecular weight $\gamma = T/T_c$ $C_p^0/C_v^0 = 5/3$

γ	$a_1 \sqrt{\frac{M}{RT_c}}$	$a_3 \sqrt{\frac{M}{RT_c}}$
0.00000E-99	0.00000E-99	$+\infty$
1.00000E-01	4.08248E-01	2.46086E+01
1.50000E-01	4.99999E-01	1.63633E+01
2.00000E-01	5.77350E-01	1.22275E+01
2.50000E-01	6.45497E-01	9.73370E-00
3.00000E-01	7.07106E-01	8.05897E-00
3.50000E-01	7.63756E-01	6.85066E-00
4.00000E-01	8.16410E-01	5.93227E-00
4.50000E-01	8.65472E-01	5.20560E-00
5.00000E-01	9.10723E-01	4.61160E-00
5.50000E-01	9.51467E-01	4.11269E-00
6.00000E-01	9.86880E-01	3.68379E-00
6.50000E-01	1.01630E-00	3.30751E-00
7.00000E-01	1.03941E-00	2.97130E-00
7.50000E-01	1.05618E-00	2.66565E-00
8.00000E-01	1.06705E-00	2.38286E-00
8.50000E-01	1.07312E-00	2.11598E-00
9.00000E-01	1.07709E-00	1.85726E-00
9.50000E-01	1.08742E-00	1.59357E-00
9.52000E-01	1.08829E-00	1.58253E-00
9.54000E-01	1.08923E-00	1.57142E-00
9.56000E-01	1.09024E-00	1.56023E-00
9.58000E-01	1.09132E-00	1.54895E-00
9.60000E-01	1.09250E-00	1.53758E-00
9.62000E-01	1.09376E-00	1.52611E-00
9.64000E-01	1.09514E-00	1.51453E-00
9.66000E-01	1.09662E-00	1.50283E-00
9.68000E-01	1.09824E-00	1.49099E-00
9.70000E-01	1.10000E-00	1.47899E-00
9.72000E-01	1.10192E-00	1.46683E-00
9.74000E-01	1.10402E-00	1.45448E-00
9.76000E-01	1.10633E-00	1.44191E-00
9.78000E-01	1.10888E-00	1.42909E-00
9.80000E-01	1.11170E-00	1.41599E-00
9.82000E-01	1.11484E-00	1.40256E-00
9.84000E-01	1.11837E-00	1.38873E-00
9.86000E-01	1.12237E-00	1.37442E-00
9.88000E-01	1.12694E-00	1.35952E-00
9.90000E-01	1.13226E-00	1.34387E-00
9.92000E-01	1.13857E-00	1.32721E-00
9.94000E-01	1.14630E-00	1.30912E-00
9.96000E-01	1.15627E-00	1.28878E-00
9.98000E-01	1.17064E-00	1.26403E-00
9.99000E-01	1.18177E-00	1.24770E-00
1.00000E-00	1.21213E-00	1.21213E-00

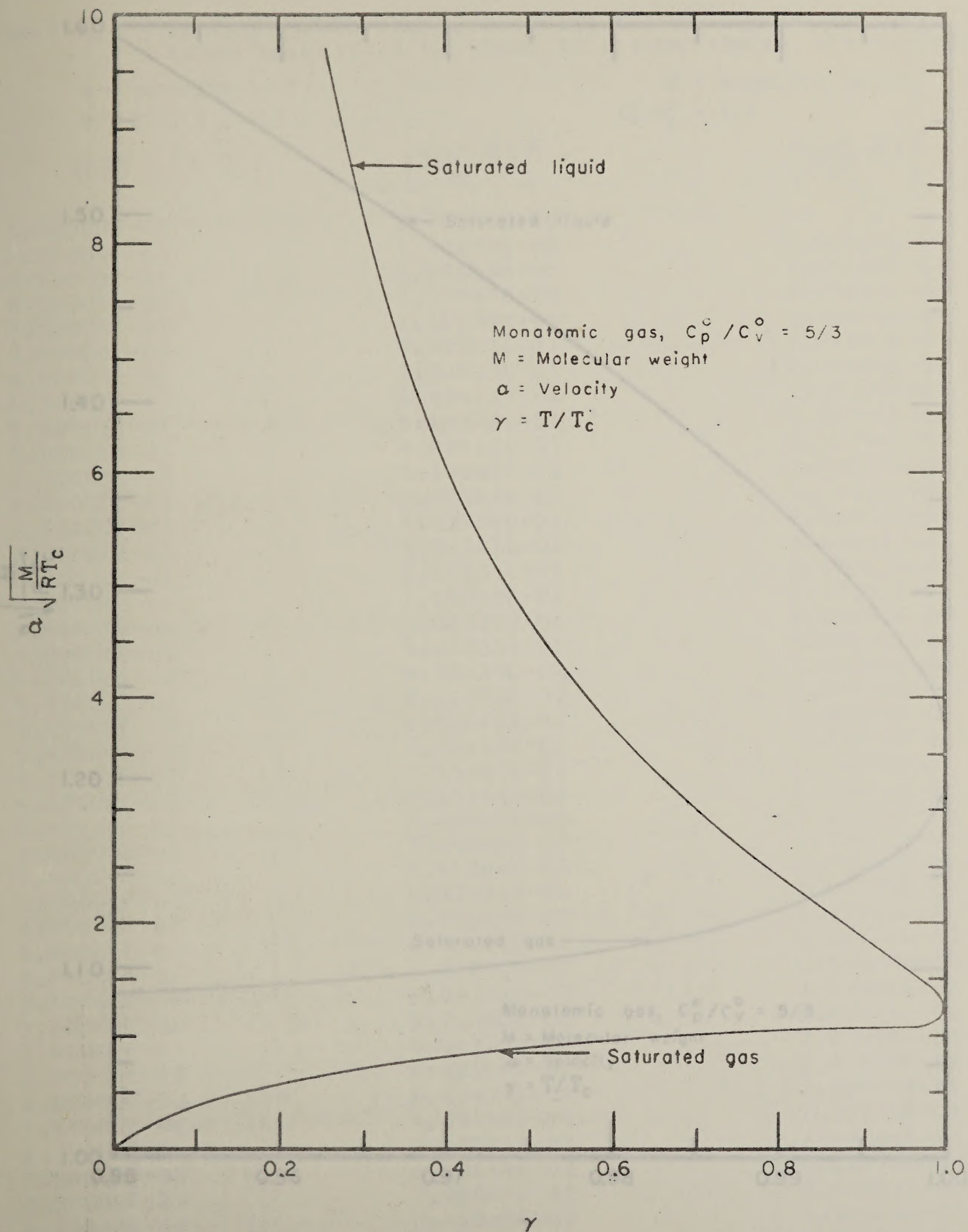


FIGURE 101.—Redlich-Kwong Fluid, Saturated Velocities of Sound as a Function of Temperature.

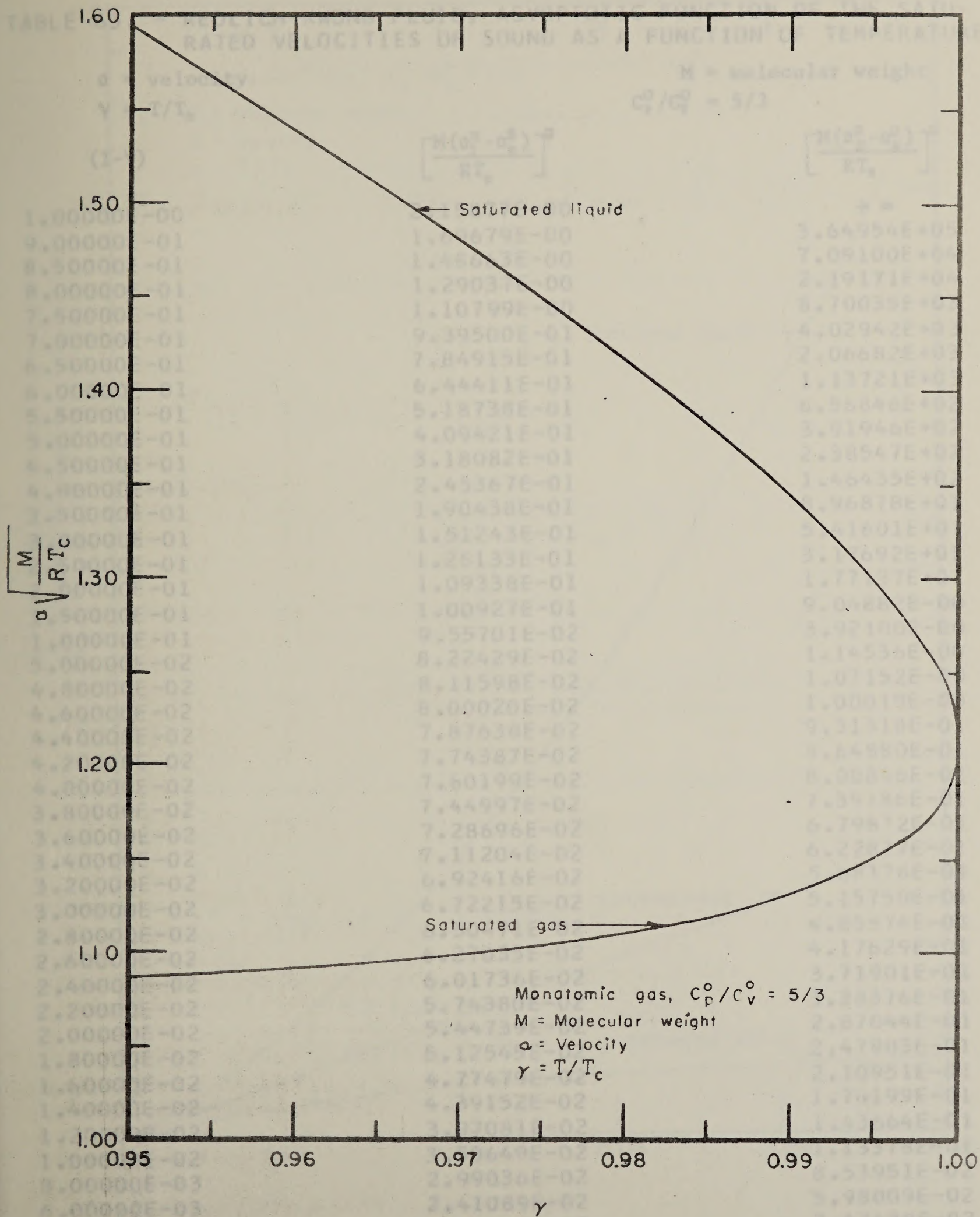


FIGURE 102.—Redlich-Kwong Fluid, Saturated Velocities of Sound as a Function of Temperature Near the Critical Point.

TABLE 63. - REDLICH-KWONG FLUID, ASYMPTOTIC FUNCTION OF THE SATURATED VELOCITIES OF SOUND AS A FUNCTION OF TEMPERATURE

 a = velocity $\gamma = T/T_c$ M = molecular weight $C_p^0/C_v^0 = 5/3$

(1- γ)	$\left[\frac{M(a_1^2 - a_c^2)}{RT_c} \right]^2$	$\left[\frac{M(a_3^2 - a_c^2)}{RT_c} \right]^2$
1.00000E-00	2.15877E-00	+ ∞
9.00000E-01	1.69679E-00	3.64954E+05
8.50000E-01	1.48663E-00	7.09100E+04
8.00000E-01	1.29037E-00	2.19171E+04
7.50000E-01	1.10799E-00	8.70035E+03
7.00000E-01	9.39500E-01	4.02942E+03
6.50000E-01	7.84915E-01	2.06682E+03
6.00000E-01	6.44411E-01	1.13721E+03
5.50000E-01	5.18738E-01	6.56846E+02
5.00000E-01	4.09421E-01	3.91946E+02
4.50000E-01	3.18082E-01	2.38547E+02
4.00000E-01	2.45367E-01	1.46435E+02
3.50000E-01	1.90438E-01	8.96878E+01
3.00000E-01	1.51243E-01	5.41601E+01
2.50000E-01	1.25133E-01	3.17692E+01
2.00000E-01	1.09338E-01	1.77137E+01
1.50000E-01	1.00927E-01	9.04882E-00
1.00000E-01	9.55701E-02	3.92100E-00
5.00000E-02	8.22429E-02	1.14536E-00
4.80000E-02	8.11598E-02	1.07152E-00
4.60000E-02	8.00020E-02	1.00019E-00
4.40000E-02	7.87638E-02	9.31318E-01
4.20000E-02	7.74387E-02	8.64880E-01
4.00000E-02	7.60199E-02	8.00846E-01
3.80000E-02	7.44997E-02	7.39186E-01
3.60000E-02	7.28696E-02	6.79872E-01
3.40000E-02	7.11204E-02	6.22877E-01
3.20000E-02	6.92416E-02	5.68178E-01
3.00000E-02	6.72215E-02	5.15750E-01
2.80000E-02	6.50471E-02	4.65574E-01
2.60000E-02	6.27035E-02	4.17629E-01
2.40000E-02	6.01736E-02	3.71901E-01
2.20000E-02	5.74380E-02	3.28376E-01
2.00000E-02	5.44739E-02	2.87044E-01
1.80000E-02	5.12545E-02	2.47903E-01
1.60000E-02	4.77479E-02	2.10951E-01
1.40000E-02	4.39152E-02	1.76199E-01
1.20000E-02	3.97081E-02	1.43664E-01
1.00000E-02	3.50649E-02	1.13378E-01
8.00000E-03	2.99036E-02	8.53951E-02
6.00000E-03	2.41089E-02	5.98009E-02
4.00000E-03	1.75049E-02	3.67438E-02
2.00000E-03	9.77613E-03	1.65117E-02
1.00000E-03	5.28337E-03	7.65314E-03
0.00000E-99	0.00000E-99	0.00000E-99

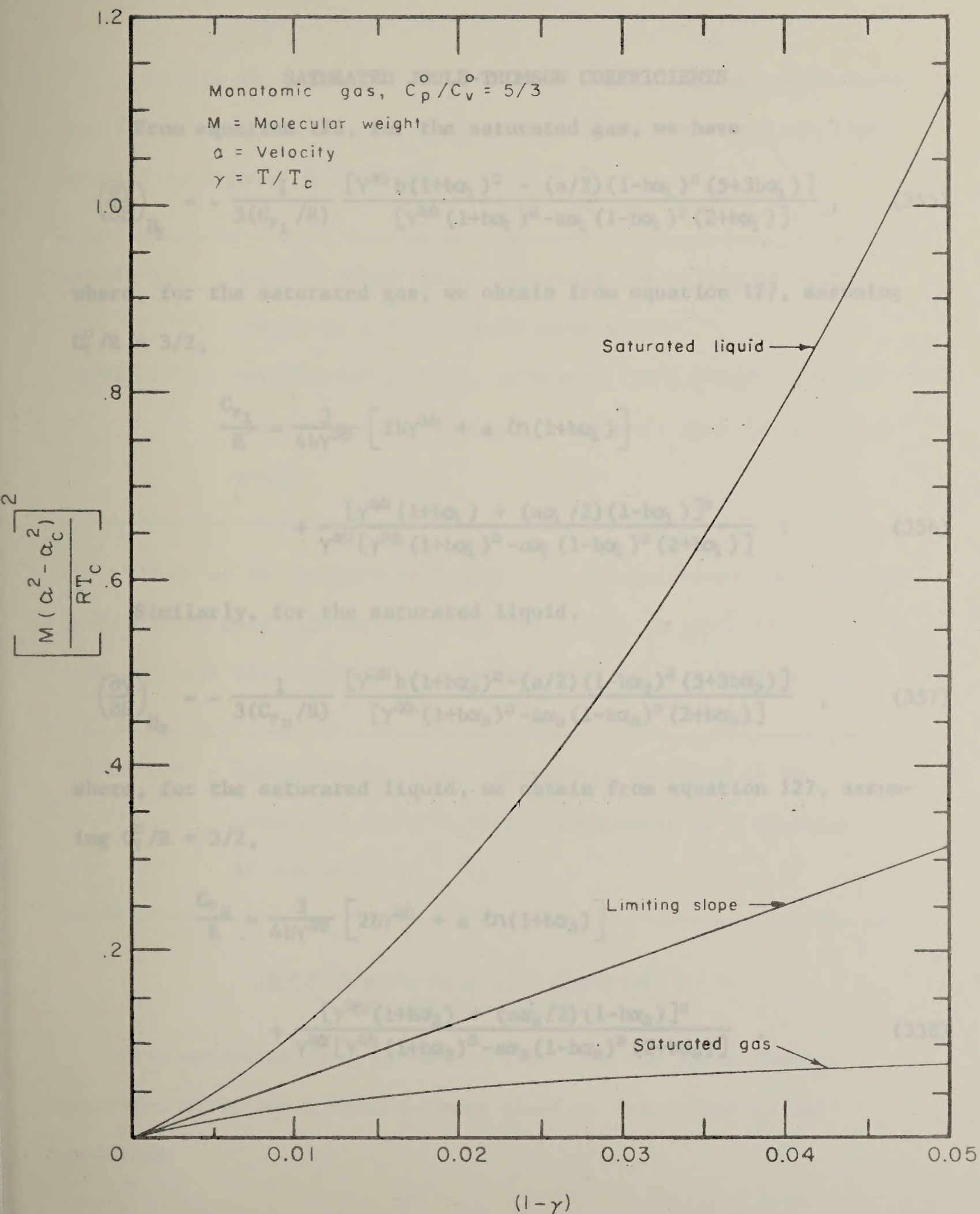


FIGURE 103.—Redlich-Kwong Fluid, Asymptotic Function of the Saturated Velocities of Sound as a Function of Temperature.

In table 64, SATURATED JOULE-THOMSON COEFFICIENTS

From equation 126, for the saturated gas, we have

$$\left(\frac{\partial \gamma}{\partial \beta}\right)_{H_1} = - \frac{1}{3(C_{P_1}/R)} \frac{[\gamma^{3/2} b(1+b\alpha_1)^2 - (a/2)(1-b\alpha_1)^2(5+3b\alpha_1)]}{[\gamma^{3/2}(1+b\alpha_1)^2 - a\alpha_1(1-b\alpha_1)^2(2+b\alpha_1)]}, \quad (355)$$

where, for the saturated gas, we obtain from equation 127, assuming

$$C_v^0/R = 3/2,$$

$$\begin{aligned} \frac{C_{P_1}}{R} = \frac{3}{4b\gamma^{3/2}} & \left[2b\gamma^{3/2} + a \ln(1+b\alpha_1) \right] \\ & + \frac{[\gamma^{3/2}(1+b\alpha_1) + (a\alpha_1/2)(1-b\alpha_1)]^2}{\gamma^{3/2}[\gamma^{3/2}(1+b\alpha_1)^2 - a\alpha_1(1-b\alpha_1)^2(2+b\alpha_1)]}. \end{aligned} \quad (356)$$

Similarly, for the saturated liquid,

$$\left(\frac{\partial \gamma}{\partial \beta}\right)_{H_3} = - \frac{1}{3(C_{P_3}/R)} \frac{[\gamma^{3/2} b(1+b\alpha_3)^2 - (a/2)(1-b\alpha_3)^2(5+3b\alpha_3)]}{[\gamma^{3/2}(1+b\alpha_3)^2 - a\alpha_3(1-b\alpha_3)^2(2+b\alpha_3)]}, \quad (357)$$

where, for the saturated liquid, we obtain from equation 127, assum-

$$\text{ing } C_v^0/R = 3/2,$$

$$\begin{aligned} \frac{C_{P_3}}{R} = \frac{3}{4b\gamma^{3/2}} & \left[2b\gamma^{3/2} + a \ln(1+b\alpha_3) \right] \\ & + \frac{[\gamma^{3/2}(1+b\alpha_3) + (a\alpha_3/2)(1-b\alpha_3)]^2}{\gamma^{3/2}[\gamma^{3/2}(1+b\alpha_3)^2 - a\alpha_3(1-b\alpha_3)^2(2+b\alpha_3)]}. \end{aligned} \quad (358)$$

In table 64, values of the saturated Joule-Thomson coefficients are listed as a function of temperature. These same data are illustrated in figures 104 and 105.

FIGURE 104. - Redlich-Kwong fluid, saturated Joule-Thomson coefficients as a function of temperature.

FIGURE 105. - Redlich-Kwong fluid, saturated Joule-Thomson coefficients as a function of temperature near the critical point.

Values of the asymptotic function of the saturated Joule-Thomson coefficients as a function of $(1-\gamma)$ are listed in table 65. These same data are illustrated, near the critical point, in figure 106.

FIGURE 106. - Redlich-Kwong fluid, asymptotic function of the saturated Joule-Thomson coefficients as a function of temperature.

JOULE-THOMSON INVERSION CURVE FOR A REDLICH-KWONG FLUID

From equations 155 and 156, we find that the Joule-Thomson inversion curve for a Redlich-Kwong fluid is determined by the equations

TABLE 64. - REDLICH-KWONG FLUID, SATURATED JOULE-THOMSON COEFFICIENTS AS A FUNCTION OF TEMPERATURE

$\gamma = T/T_c$	$\beta = P/P_c$	$C_p^0/C_v^0 = 5/3$
γ	$\left(\frac{\partial \gamma}{\partial \beta}\right)_{H_1}$	$\left(\frac{\partial \gamma}{\partial \beta}\right)_{H_3}$
0.00000E-99	$+\infty$	0.00000E-99
1.00000E-01	1.34834E+01	-1.02248E-03
1.50000E-01	7.32367E-00	-1.80985E-03
2.00000E-01	4.74471E-00	-2.66396E-03
2.50000E-01	3.38518E-00	-3.53234E-03
3.00000E-01	2.56690E-00	-4.37004E-03
3.50000E-01	2.02985E-00	-5.13477E-03
4.00000E-01	1.65523E-00	-5.78309E-03
4.50000E-01	1.38203E-00	-6.26627E-03
5.00000E-01	1.17606E-00	-6.52490E-03
5.50000E-01	1.01661E-00	-6.48105E-03
6.00000E-01	8.90226E-01	-6.02630E-03
6.50000E-01	7.87627E-01	-5.00191E-03
7.00000E-01	7.02157E-01	-3.16406E-03
7.50000E-01	6.28751E-01	-1.17990E-04
8.00000E-01	5.63147E-01	4.81828E-03
8.50000E-01	5.01053E-01	1.29321E-02
9.00000E-01	4.36747E-01	2.70101E-02
9.50000E-01	3.58860E-01	5.48602E-02
9.52000E-01	3.55113E-01	5.65430E-02
9.54000E-01	3.51289E-01	5.82949E-02
9.56000E-01	3.47382E-01	6.01208E-02
9.58000E-01	3.43386E-01	6.20263E-02
9.60000E-01	3.39294E-01	6.40172E-02
9.62000E-01	3.35100E-01	6.61005E-02
9.64000E-01	3.30796E-01	6.82840E-02
9.66000E-01	3.26371E-01	7.05764E-02
9.68000E-01	3.21815E-01	7.29878E-02
9.70000E-01	3.17116E-01	7.55301E-02
9.72000E-01	3.12260E-01	7.82167E-02
9.74000E-01	3.07230E-01	8.10639E-02
9.76000E-01	3.02006E-01	8.40909E-02
9.78000E-01	2.96565E-01	8.73209E-02
9.80000E-01	2.90876E-01	9.07826E-02
9.82000E-01	2.84904E-01	9.45119E-02
9.84000E-01	2.78601E-01	9.85549E-02
9.86000E-01	2.71907E-01	1.02972E-01
9.88000E-01	2.64737E-01	1.07847E-01
9.90000E-01	2.56971E-01	1.13299E-01
9.92000E-01	2.48426E-01	1.19511E-01
9.94000E-01	2.38795E-01	1.26789E-01
9.96000E-01	2.27481E-01	1.35729E-01
9.98000E-01	2.12954E-01	1.47859E-01
9.99000E-01	2.02856E-01	1.56750E-01
1.00000E-00	1.79197E-01	1.79197E-01

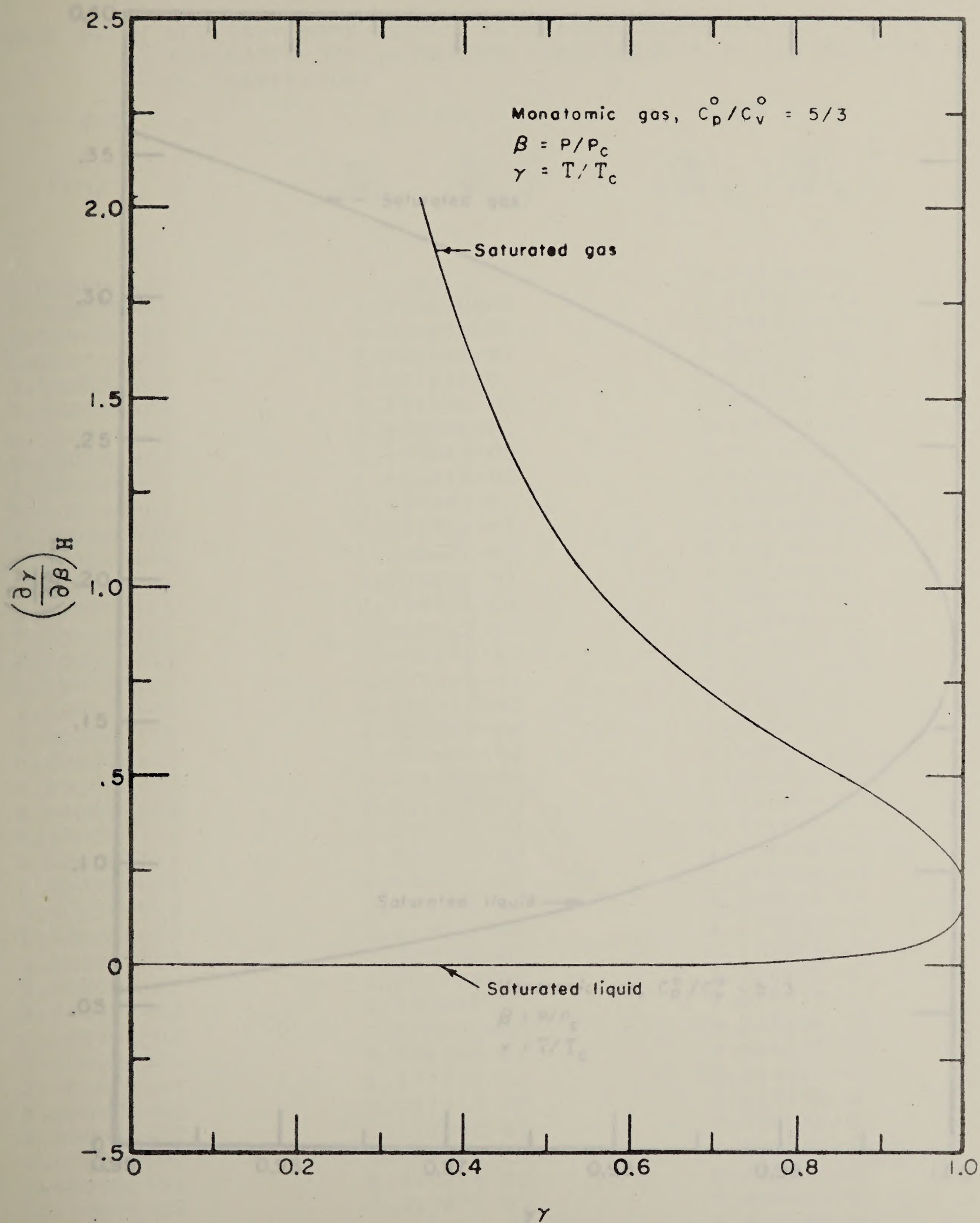


FIGURE 104.-Redlich - Kwong Fluid, Saturated Joule - Thomson Coefficients as a Function of Temperature.

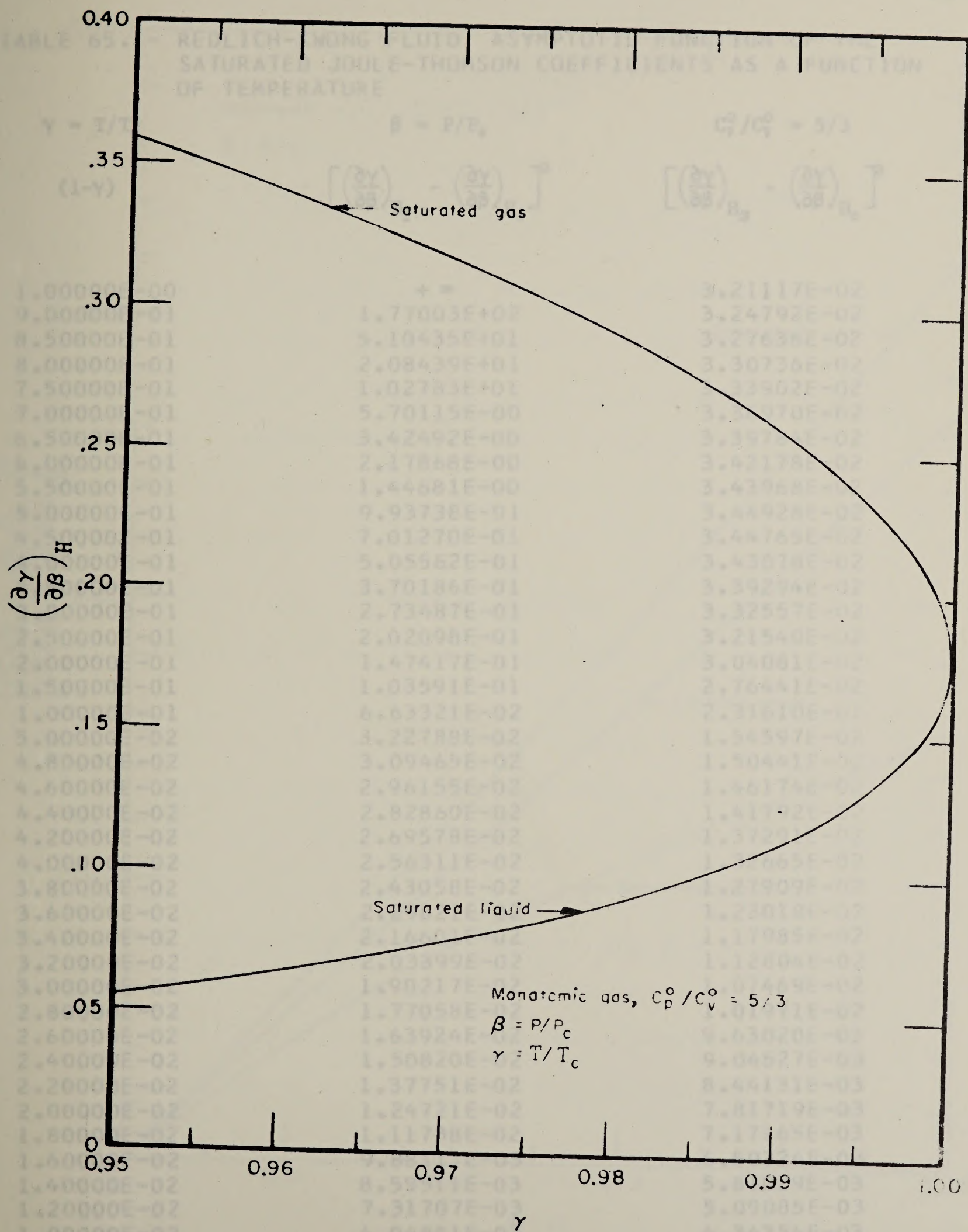


FIGURE 105.—Redlich-Kwong Fluid, Saturated Joule-Thomson Coefficients as a Function of Temperature Near the Critical Point.

TABLE 65. - REDLICH-KWONG FLUID, ASYMPTOTIC FUNCTION OF THE SATURATED JOULE-THOMSON COEFFICIENTS AS A FUNCTION OF TEMPERATURE

$\gamma = T/T_c$	$\beta = P/P_c$	$C_p^0/C_v^0 = 5/3$
(1- γ)	$\left[\left(\frac{\partial \gamma}{\partial \beta} \right)_{H_1} - \left(\frac{\partial \gamma}{\partial \beta} \right)_{H_c} \right]^2$	$\left[\left(\frac{\partial \gamma}{\partial \beta} \right)_{H_3} - \left(\frac{\partial \gamma}{\partial \beta} \right)_{H_c} \right]^2$
1.00000E-00	+ ∞	3.21117E-02
9.00000E-01	1.77003E+02	3.24792E-02
8.50000E-01	5.10435E+01	3.27636E-02
8.00000E-01	2.08439E+01	3.30736E-02
7.50000E-01	1.02783E+01	3.33902E-02
7.00000E-01	5.70115E-00	3.36970E-02
6.50000E-01	3.42492E-00	3.39784E-02
6.00000E-01	2.17868E-00	3.42178E-02
5.50000E-01	1.44681E-00	3.43968E-02
5.00000E-01	9.93738E-01	3.44928E-02
4.50000E-01	7.01270E-01	3.44765E-02
4.00000E-01	5.05562E-01	3.43078E-02
3.50000E-01	3.70186E-01	3.39294E-02
3.00000E-01	2.73487E-01	3.32557E-02
2.50000E-01	2.02098E-01	3.21540E-02
2.00000E-01	1.47417E-01	3.04081E-02
1.50000E-01	1.03591E-01	2.76441E-02
1.00000E-01	6.63321E-02	2.31610E-02
5.00000E-02	3.22788E-02	1.54597E-02
4.80000E-02	3.09465E-02	1.50441E-02
4.60000E-02	2.96155E-02	1.46174E-02
4.40000E-02	2.82860E-02	1.41792E-02
4.20000E-02	2.69578E-02	1.37291E-02
4.00000E-02	2.56311E-02	1.32665E-02
3.80000E-02	2.43058E-02	1.27909E-02
3.60000E-02	2.29821E-02	1.23018E-02
3.40000E-02	2.16601E-02	1.17985E-02
3.20000E-02	2.03399E-02	1.12804E-02
3.00000E-02	1.90217E-02	1.07469E-02
2.80000E-02	1.77058E-02	1.01971E-02
2.60000E-02	1.63924E-02	9.63020E-03
2.40000E-02	1.50820E-02	9.04527E-03
2.20000E-02	1.37751E-02	8.44131E-03
2.00000E-02	1.24721E-02	7.81719E-03
1.80000E-02	1.11738E-02	7.17165E-03
1.60000E-02	9.88117E-03	6.50324E-03
1.40000E-02	8.59511E-03	5.81029E-03
1.20000E-02	7.31707E-03	5.09085E-03
1.00000E-02	6.04881E-03	4.34254E-03
8.00000E-03	4.79265E-03	3.56241E-03
6.00000E-03	3.55186E-03	2.74657E-03
4.00000E-03	2.33131E-03	1.88950E-03
2.00000E-03	1.13951E-03	9.82049E-04
1.00000E-03	5.59755E-04	5.03856E-04
0.00000E-99	0.00000E-99	0.00000E-99

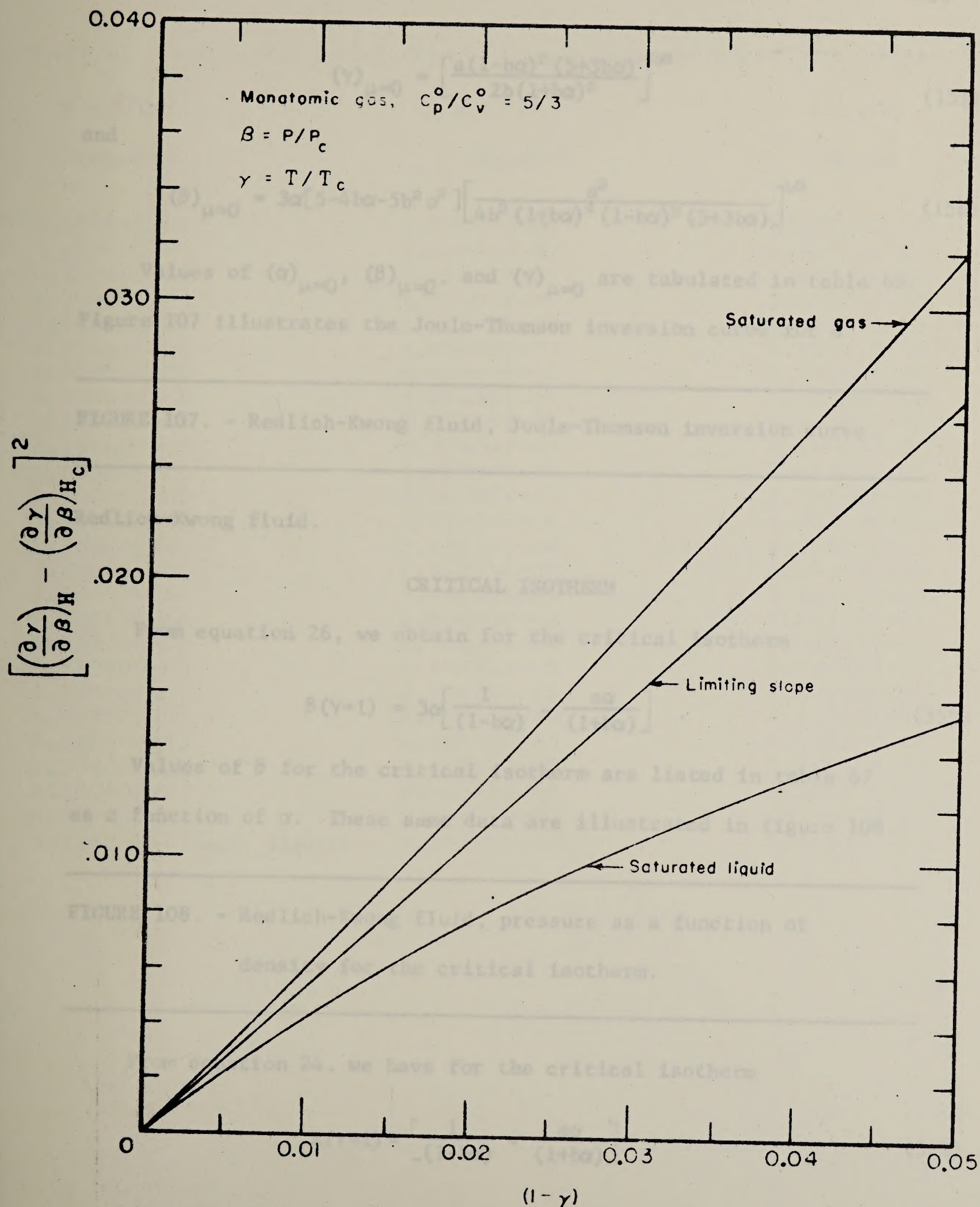


FIGURE 106.—Redlich-Kwong Fluid, Asymptotic Function of the Saturated Joule-Thomson Coefficients as a Function of Temperature.

$$(\gamma)_{\mu=0} = \left[\frac{a(1-b\alpha)^2(5+3b\alpha)}{2b(1+b\alpha)^2} \right]^{2\beta} \quad (155)$$

and

$$(\beta)_{\mu=0} = 3\alpha[5-4b\alpha-5b^2\alpha^2] \left[\frac{a^2}{4b^2(1+b\alpha)^4(1-b\alpha)^2(5+3b\alpha)} \right]^{1/3} \quad (156)$$

Values of $(\alpha)_{\mu=0}$, $(\beta)_{\mu=0}$, and $(\gamma)_{\mu=0}$ are tabulated in table 66.

Figure 107 illustrates the Joule-Thomson inversion curve for a

FIGURE 107. - Redlich-Kwong fluid, Joule-Thomson inversion curve.

Redlich-Kwong fluid.

CRITICAL ISOTHERM

From equation 26, we obtain for the critical isotherm

$$\beta(\gamma=1) = 3\alpha \left[\frac{1}{(1-b\alpha)} - \frac{a\alpha}{(1+b\alpha)} \right] \quad (359)$$

Values of β for the critical isotherm are listed in table 67 as a function of α . These same data are illustrated in figure 108.

FIGURE 108. - Redlich-Kwong fluid, pressure as a function of density for the critical isotherm.

From equation 24, we have for the critical isotherm

$$Z(\gamma=1) = \left[\frac{1}{(1-b\alpha)} - \frac{a\alpha}{(1+b\alpha)} \right] \quad (360)$$

TABLE 66. - REDLICH-KWONG FLUID, JOULE-THOMSON INVERSION CURVE

$\gamma = T/T_c$	$\alpha = \rho/\rho_c$	$\beta = P/P_c$
$(\gamma)_{\mu=0}$	$(\alpha)_{\mu=0}$	$(\beta)_{\mu=0}$
5.33855E-00	0.00000E-99	0.00000E-99
5.25000E-00	2.83804E-02	4.48972E-01
5.00000E-00	1.11002E-01	1.69389E-00
4.75000E-00	1.97537E-01	2.90174E-00
4.50000E-00	2.88292E-01	4.06697E-00
4.25000E-00	3.83605E-01	5.18291E-00
4.00000E-00	4.83860E-01	6.24154E-00
3.75000E-00	5.89490E-01	7.23308E-00
3.50000E-00	7.00989E-01	8.14546E-00
3.25000E-00	8.18924E-01	8.96360E-00
3.00000E-00	9.43952E-01	9.66838E-00
2.89265E-00	1.00000E-00	9.93032E-00
2.75000E-00	1.07684E-00	1.02350E+01
2.50000E-00	1.21851E-00	1.06310E+01
2.25000E-00	1.37005E-00	1.08122E+01
2.20101E-00	1.40102E-00	1.08177E+01
2.00000E-00	1.53283E-00	1.07171E+01
1.75000E-00	1.70853E-00	1.02563E+01
1.50000E-00	1.89936E-00	9.29402E-00
1.25000E-00	2.10827E-00	7.60985E-00
1.00000E-00	2.33947E-00	4.81331E-00
9.50000E-01	2.38890E-00	4.06326E-00
9.00000E-01	2.43953E-00	3.23096E-00
8.50000E-01	2.49144E-00	2.30533E-00
8.00000E-01	2.54471E-00	1.27301E-00
7.51525E-01(sat. liquid)	2.59775E-00	1.54951E-01

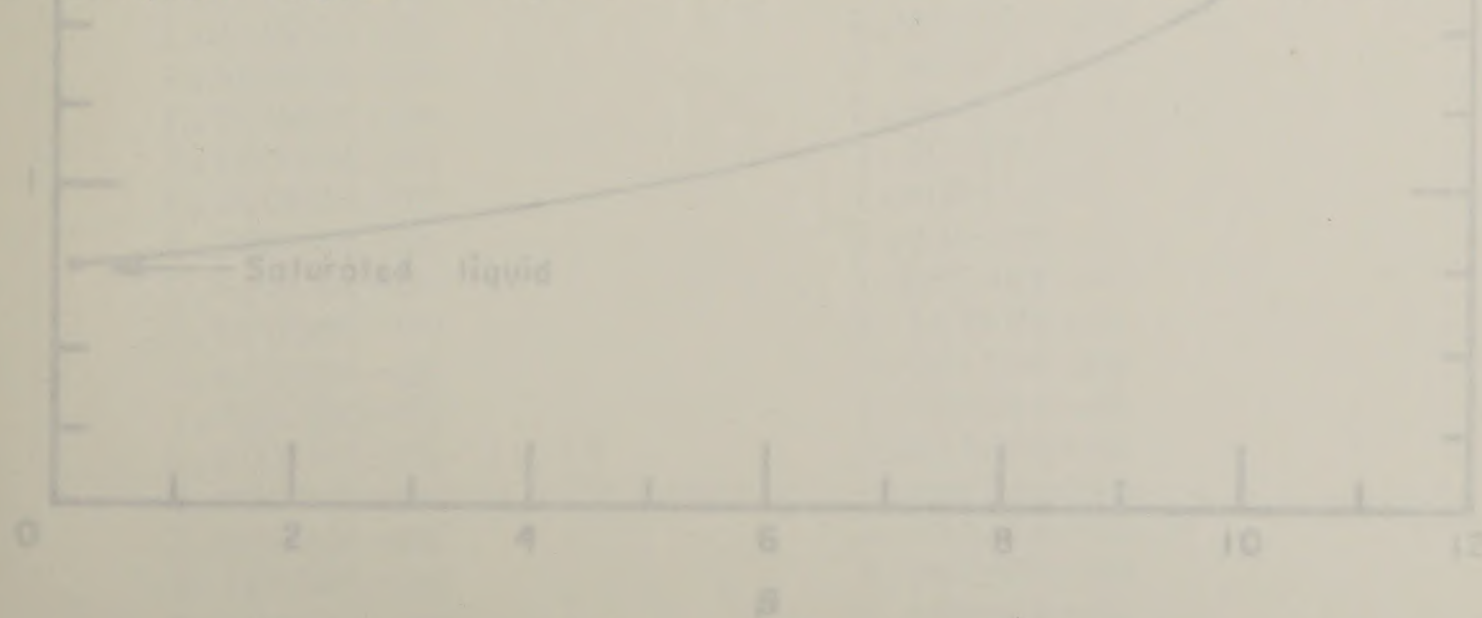


FIGURE 107. - Redlich-Kwong Fluid, Joule-Thomson Inversion Curve

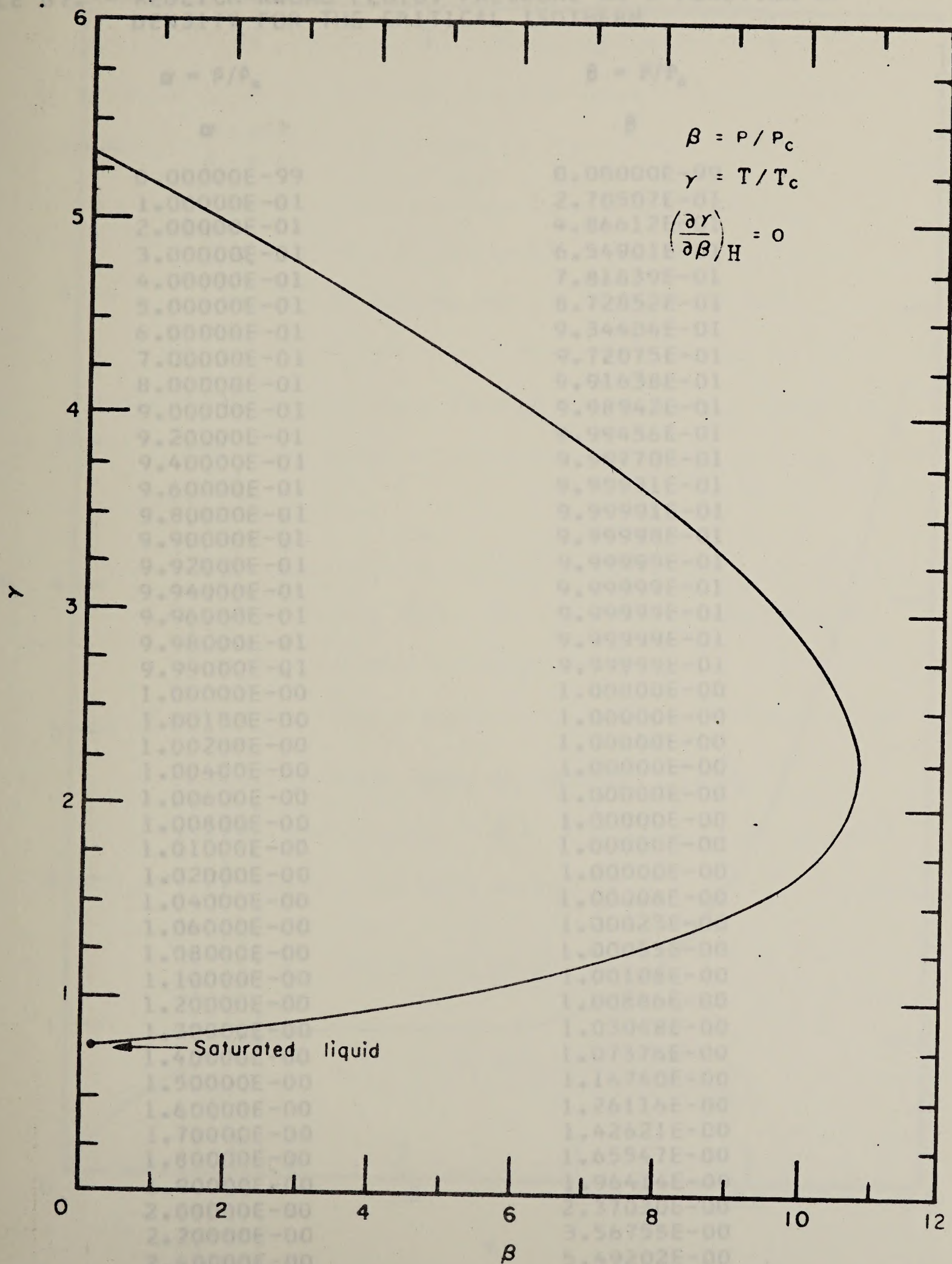


FIGURE 107. - Redlich-Kwong Fluid, Joule-Thomson Inversion Curve.

TABLE 67. - REDLICH-KWONG FLUID, PRESSURE AS A FUNCTION OF DENSITY FOR THE CRITICAL ISOTHERM

$\alpha = \rho/\rho_c$	$\beta = P/P_c$
α	β
0.00000E-99	0.00000E-99
1.00000E-01	2.70507E-01
2.00000E-01	4.86612E-01
3.00000E-01	6.54901E-01
4.00000E-01	7.81639E-01
5.00000E-01	8.72852E-01
6.00000E-01	9.34404E-01
7.00000E-01	9.72075E-01
8.00000E-01	9.91638E-01
9.00000E-01	9.98942E-01
9.20000E-01	9.99456E-01
9.40000E-01	9.99770E-01
9.60000E-01	9.99931E-01
9.80000E-01	9.99991E-01
9.90000E-01	9.99998E-01
9.92000E-01	9.99999E-01
9.94000E-01	9.99999E-01
9.96000E-01	9.99999E-01
9.98000E-01	9.99999E-01
9.99000E-01	9.99999E-01
1.00000E-00	1.00000E-00
1.00100E-00	1.00000E-00
1.00200E-00	1.00000E-00
1.00400E-00	1.00000E-00
1.00600E-00	1.00000E-00
1.00800E-00	1.00000E-00
1.01000E-00	1.00000E-00
1.02000E-00	1.00000E-00
1.04000E-00	1.00006E-00
1.06000E-00	1.00023E-00
1.08000E-00	1.00055E-00
1.10000E-00	1.00108E-00
1.20000E-00	1.00886E-00
1.30000E-00	1.03048E-00
1.40000E-00	1.07376E-00
1.50000E-00	1.14740E-00
1.60000E-00	1.26116E-00
1.70000E-00	1.42621E-00
1.80000E-00	1.65547E-00
1.90000E-00	1.96414E-00
2.00000E-00	2.37030E-00
2.20000E-00	3.56755E-00
2.40000E-00	5.49202E-00
2.60000E-00	8.53909E-00
2.80000E-00	1.33995E+01
3.00000E-00	2.14097E+01
3.20000E-00	3.55494E+01
3.40000E-00	6.41179E+01
3.60000E-00	1.42245E+02
3.84732E-00	+ ∞

FIGURE

Redlich-Kwong Fluid, Pressure as a Function of Density for the Critical Isotherm

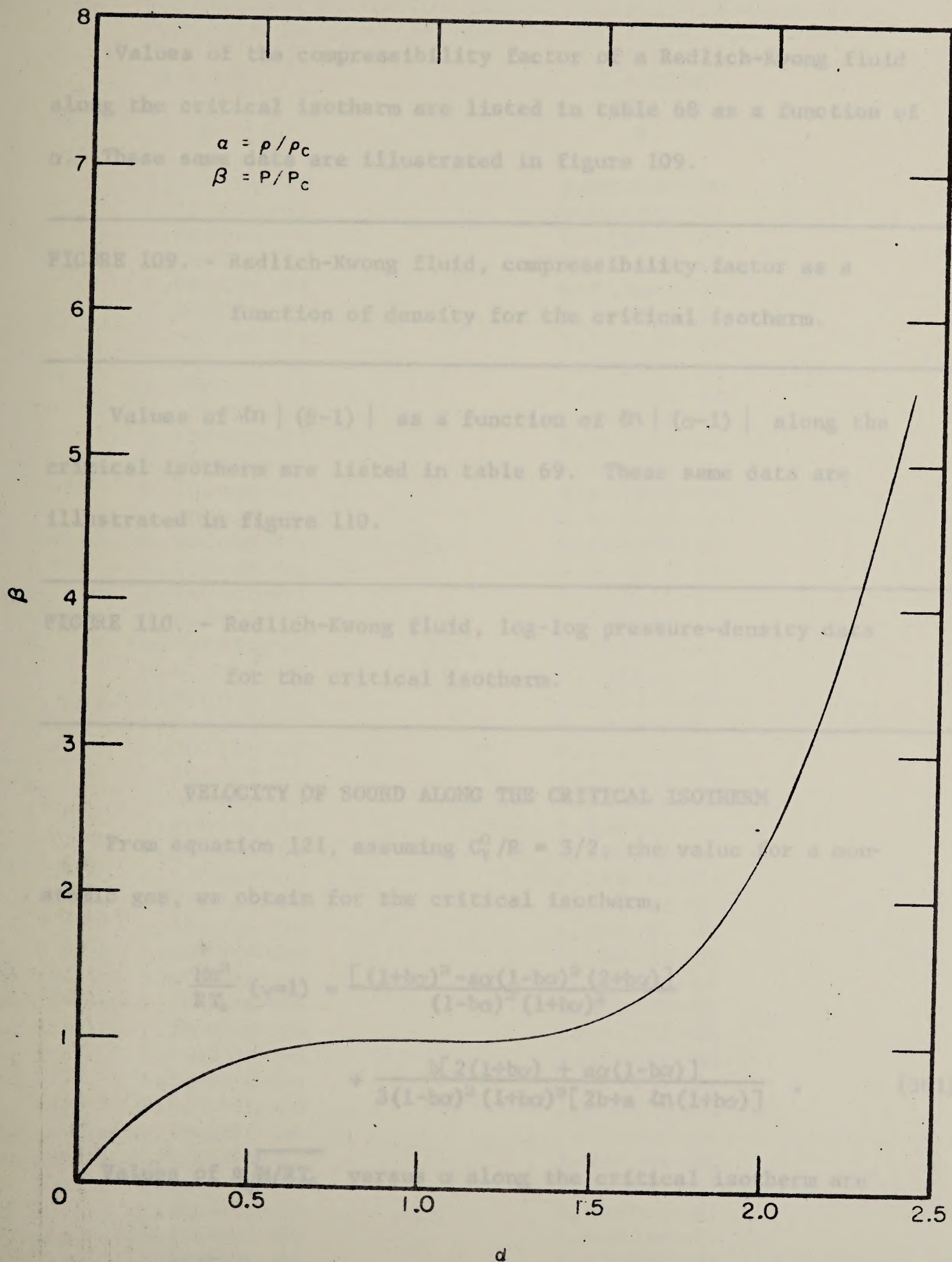


FIGURE 108.—Redlich-Kwong Fluid, Pressure as a Function of Density for the Critical Isotherm.

Values of the compressibility factor of a Redlich-Kwong fluid along the critical isotherm are listed in table 68 as a function of α . These same data are illustrated in figure 109.

FIGURE 109. - Redlich-Kwong fluid, compressibility factor as a function of density for the critical isotherm.

Values of $\ln |(\beta-1)|$ as a function of $\ln |(\alpha-1)|$ along the critical isotherm are listed in table 69. These same data are illustrated in figure 110.

FIGURE 110. - Redlich-Kwong fluid, log-log pressure-density data for the critical isotherm.

VELOCITY OF SOUND ALONG THE CRITICAL ISOTHERM

From equation 121, assuming $C_v^0/R = 3/2$, the value for a monatomic gas, we obtain for the critical isotherm,

$$\frac{Ma^2}{RT_c} (\gamma=1) = \frac{[(1+b\alpha)^2 - a\alpha(1-b\alpha)^2(2+b\alpha)]}{(1-b\alpha)^2(1+b\alpha)^2} + \frac{b[2(1+b\alpha) + a\alpha(1-b\alpha)]}{3(1-b\alpha)^2(1+b\alpha)^2[2b+a \ln(1+b\alpha)]} \quad (361)$$

Values of $a\sqrt{M/RT_c}$ versus α along the critical isotherm are

TABLE 68. - REDLICH-KWONG FLUID, COMPRESSIBILITY FACTOR AS A FUNCTION OF DENSITY FOR THE CRITICAL ISOTHERM

$\alpha = \rho/\rho_c$	$Z = P/\rho RT$
α	Z
0.00000E-99	1.00000E-00
1.00000E-01	9.01690E-01
2.00000E-01	8.11021E-01
3.00000E-01	7.27668E-01
4.00000E-01	6.51366E-01
5.00000E-01	5.81901E-01
6.00000E-01	5.19113E-01
7.00000E-01	4.62893E-01
8.00000E-01	4.13182E-01
9.00000E-01	3.69978E-01
9.20000E-01	3.62122E-01
9.40000E-01	3.54528E-01
9.60000E-01	3.47198E-01
9.80000E-01	3.40133E-01
9.90000E-01	3.36699E-01
9.92000E-01	3.36021E-01
9.94000E-01	3.35345E-01
9.96000E-01	3.34671E-01
9.98000E-01	3.34001E-01
9.99000E-01	3.33666E-01
1.00000E-00	3.33333E-01
1.00100E-00	3.33000E-01
1.00200E-00	3.32668E-01
1.00400E-00	3.32005E-01
1.00600E-00	3.31345E-01
1.00800E-00	3.30688E-01
1.01000E-00	3.30033E-01
1.02000E-00	3.26800E-01
1.04000E-00	3.20534E-01
1.06000E-00	3.14538E-01
1.08000E-00	3.08813E-01
1.10000E-00	3.03360E-01
1.20000E-00	2.80239E-01
1.30000E-00	2.64225E-01
1.40000E-00	2.55659E-01
1.50000E-00	2.54979E-01
1.60000E-00	2.62743E-01
1.70000E-00	2.79650E-01
1.80000E-00	3.06570E-01
1.90000E-00	3.44586E-01
2.00000E-00	3.95050E-01
2.20000E-00	5.40538E-01
2.40000E-00	7.62781E-01
2.60000E-00	1.09475E-00
2.80000E-00	1.59519E-00
3.00000E-00	2.37886E-00
3.20000E-00	3.70306E-00
3.40000E-00	6.28607E-00
3.60000E-00	1.31708E+01
3.84732E-00	+ ∞

FIGURE

-Kwong Fluid,

Factor as a
Isotherm.

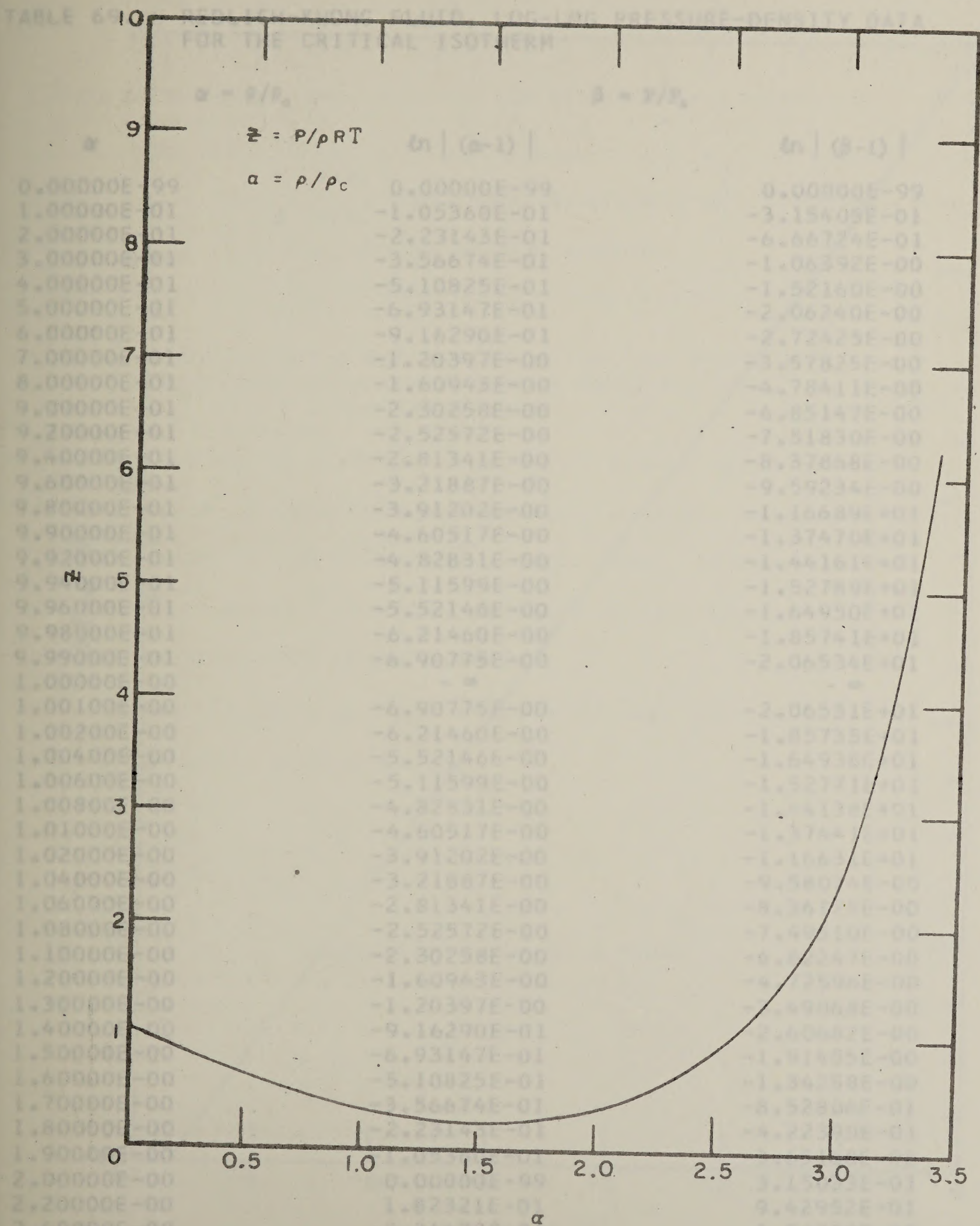


FIGURE 109.—Redlich-Kwong Fluid, Compressibility Factor as a Function of Density for the Critical Isotherm.

TABLE 69. - REDLICH-KWONG FLUID, LOG-LOG PRESSURE-DENSITY DATA
FOR THE CRITICAL ISOTHERM

$\alpha = p/p_c$	$\beta = P/P_c$	
α	$\ln (\alpha-1) $	$\ln (\beta-1) $
0.00000E-99	0.00000E-99	0.00000E-99
1.00000E-01	-1.05360E-01	-3.15405E-01
2.00000E-01	-2.23143E-01	-6.66724E-01
3.00000E-01	-3.56674E-01	-1.06392E-00
4.00000E-01	-5.10825E-01	-1.52160E-00
5.00000E-01	-6.93147E-01	-2.06240E-00
6.00000E-01	-9.16290E-01	-2.72425E-00
7.00000E-01	-1.20397E-00	-3.57825E-00
8.00000E-01	-1.60943E-00	-4.78411E-00
9.00000E-01	-2.30258E-00	-6.85147E-00
9.20000E-01	-2.52572E-00	-7.51830E-00
9.40000E-01	-2.81341E-00	-8.37868E-00
9.60000E-01	-3.21887E-00	-9.59234E-00
9.80000E-01	-3.91202E-00	-1.16689E+01
9.90000E-01	-4.60517E-00	-1.37470E+01
9.92000E-01	-4.82831E-00	-1.44161E+01
9.94000E-01	-5.11599E-00	-1.52789E+01
9.96000E-01	-5.52146E-00	-1.64950E+01
9.98000E-01	-6.21460E-00	-1.85741E+01
9.99000E-01	-6.90775E-00	-2.06534E+01
1.00000E-00	- ∞	- ∞
1.00100E-00	-6.90775E-00	-2.06531E+01
1.00200E-00	-6.21460E-00	-1.85735E+01
1.00400E-00	-5.52146E-00	-1.64938E+01
1.00600E-00	-5.11599E-00	-1.52771E+01
1.00800E-00	-4.82831E-00	-1.44138E+01
1.01000E-00	-4.60517E-00	-1.37441E+01
1.02000E-00	-3.91202E-00	-1.16631E+01
1.04000E-00	-3.21887E-00	-9.58074E-00
1.06000E-00	-2.81341E-00	-8.36128E-00
1.08000E-00	-2.52572E-00	-7.49510E-00
1.10000E-00	-2.30258E-00	-6.82247E-00
1.20000E-00	-1.60943E-00	-4.72596E-00
1.30000E-00	-1.20397E-00	-3.49068E-00
1.40000E-00	-9.16290E-01	-2.60682E-00
1.50000E-00	-6.93147E-01	-1.91455E-00
1.60000E-00	-5.10825E-01	-1.34258E-00
1.70000E-00	-3.56674E-01	-8.52806E-01
1.80000E-00	-2.23143E-01	-4.22390E-01
1.90000E-00	-1.05360E-01	-3.65160E-02
2.00000E-00	0.00000E-99	3.15033E-01
2.20000E-00	1.82321E-01	9.42952E-01
2.40000E-00	3.36472E-01	1.50230E-00
2.60000E-00	4.70003E-01	2.02010E-00
2.80000E-00	5.87786E-01	2.51766E-00
3.00000E-00	6.93147E-01	3.01601E-00
3.20000E-00	7.88457E-01	3.54239E-00
3.40000E-00	8.75468E-01	4.14500E-00
3.60000E-00	9.55511E-01	4.95049E-00
3.84732E-00	1.04637E-00	+ ∞

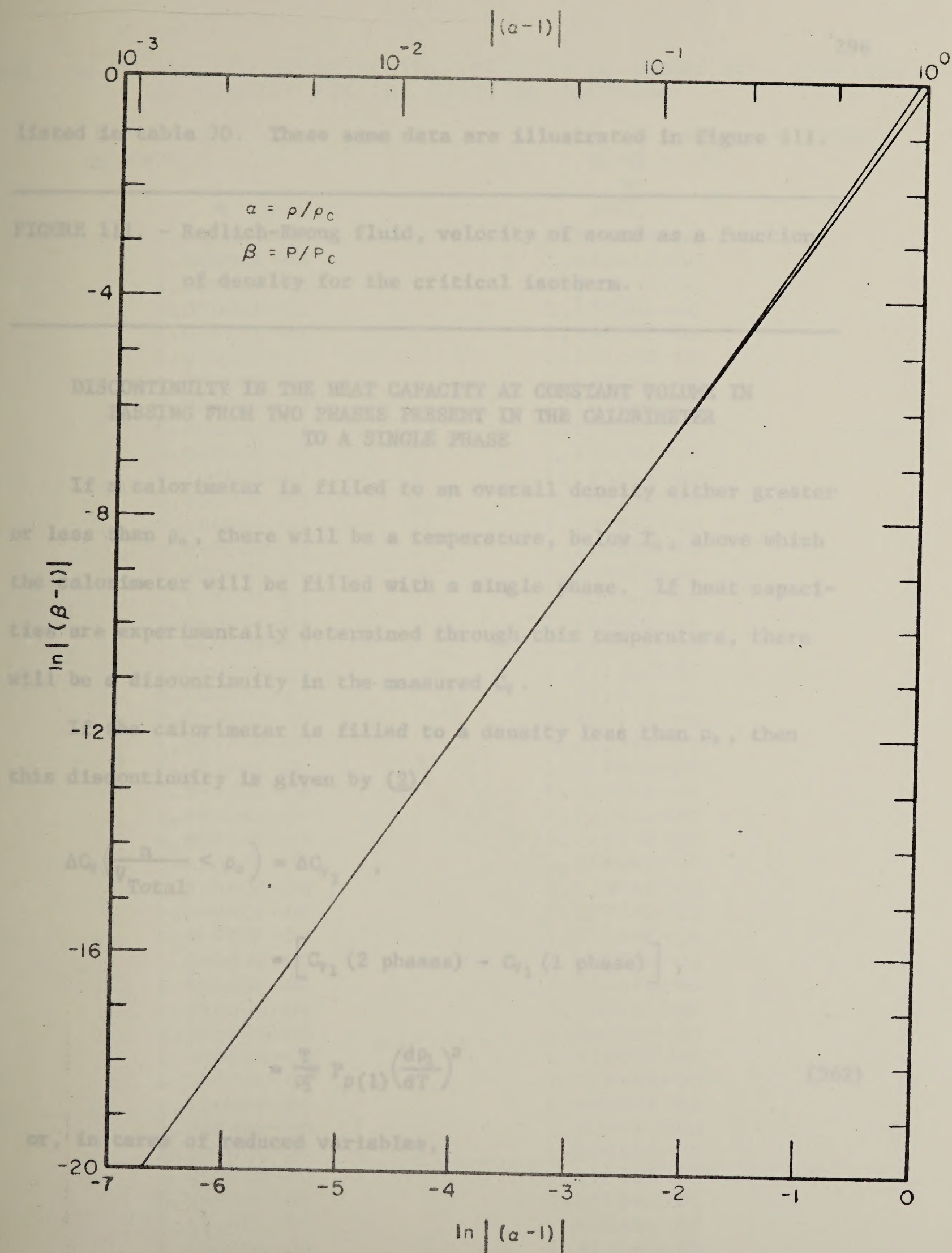


FIGURE 110.—Redlich-Kwong Fluid, Log-Log Pressure-Density Data for the Critical Isotherm.

listed in table 70. These same data are illustrated in figure 111.

FIGURE 111. - Redlich-Kwong fluid, velocity of sound as a function of density for the critical isotherm.

DISCONTINUITY IN THE HEAT CAPACITY AT CONSTANT VOLUME IN
PASSING FROM TWO PHASES PRESENT IN THE CALORIMETER
TO A SINGLE PHASE

If a calorimeter is filled to an overall density either greater or less than ρ_c , there will be a temperature, below T_c , above which the calorimeter will be filled with a single phase. If heat capacities are experimentally determined through this temperature, there will be a discontinuity in the measured C_v .

If the calorimeter is filled to a density less than ρ_c , then this discontinuity is given by (2)

$$\begin{aligned} \Delta C_v \left(\frac{n}{V_{\text{Total}}} < \rho_c \right) &= \Delta C_{v1} , \\ &= \left[C_{v1} (2 \text{ phases}) - C_{v1} (1 \text{ phase}) \right] , \\ &= \frac{T}{\rho_1^2} P_{\rho(1)} \left(\frac{d\rho_1}{dT} \right)^2 \end{aligned} \quad (362)$$

or, in terms of reduced variables,

TABLE 70. - REDLICH-KWONG FLUID, VELOCITY OF SOUND AS A FUNCTION OF DENSITY FOR THE CRITICAL ISOTHERM

 α = velocity $\alpha = \rho/\rho_c$

M = molecular weight

 $C_p^0/C_v^0 = 5/3$ $\alpha \sqrt{\frac{M}{RT_c}}$

0.000000E-99	1.29099E-00
1.00000E-01	1.24541E-00
2.00000E-01	1.20733E-00
3.00000E-01	1.17710E-00
4.00000E-01	1.15510E-00
5.00000E-01	1.14169E-00
6.00000E-01	1.13718E-00
7.00000E-01	1.14184E-00
8.00000E-01	1.15583E-00
9.00000E-01	1.17926E-00
9.20000E-01	1.18508E-00
9.40000E-01	1.19127E-00
9.60000E-01	1.19785E-00
9.80000E-01	1.20480E-00
9.90000E-01	1.20842E-00
9.92000E-01	1.20916E-00
9.94000E-01	1.20989E-00
9.96000E-01	1.21064E-00
9.98000E-01	1.21138E-00
9.99000E-01	1.21176E-00
1.00000E-00	1.21213E-00
1.00100E-00	1.21251E-00
1.00200E-00	1.21289E-00
1.00400E-00	1.21364E-00
1.00600E-00	1.21441E-00
1.00800E-00	1.21517E-00
1.01000E-00	1.21594E-00
1.02000E-00	1.21984E-00
1.04000E-00	1.22793E-00
1.06000E-00	1.23639E-00
1.08000E-00	1.24523E-00
1.10000E-00	1.25445E-00
1.20000E-00	1.30618E-00
1.30000E-00	1.36734E-00
1.40000E-00	1.43801E-00
1.50000E-00	1.51840E-00
1.60000E-00	1.60883E-00
1.70000E-00	1.70985E-00
1.80000E-00	1.82218E-00
1.90000E-00	1.94686E-00
2.00000E-00	2.08524E-00
2.20000E-00	2.41064E-00
2.40000E-00	2.81976E-00
2.60000E-00	3.34905E-00
2.80000E-00	4.06402E-00
3.00000E-00	5.09293E-00
3.20000E-00	6.72329E-00
3.40000E-00	9.75734E-00
3.60000E-00	1.75923E+01
3.84732E-00	+ ∞

FIGURE 70. - Redlich-Kwong Fluid, Velocity of Sound as a Function of Density for the Critical Isotherm.

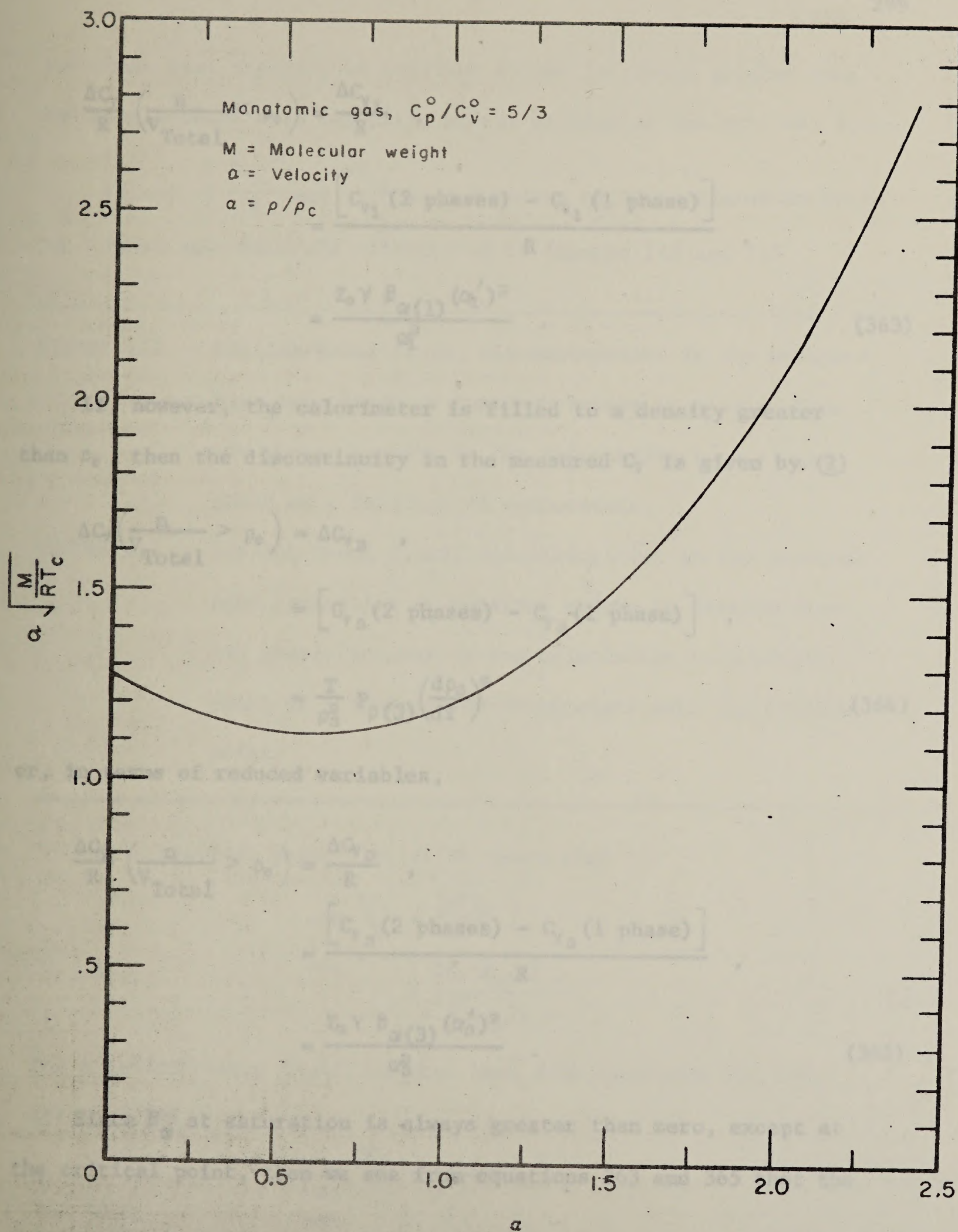


FIGURE III.—Redlich—Kwong Fluid, Velocity of Sound as a Function of Density for the Critical Isotherm.

$$\frac{\Delta C_v}{R} \left(\frac{n}{V_{\text{Total}}} < \rho_c \right) = \frac{\Delta C_{v1}}{R} ,$$

$$= \frac{[C_{v1} (2 \text{ phases}) - C_{v1} (1 \text{ phase})]}{R} ,$$

$$= \frac{Z_c \gamma \beta_{\alpha(1)} (\alpha'_1)^2}{\alpha_1^2} . \quad (363)$$

If, however, the calorimeter is filled to a density greater than ρ_c , then the discontinuity in the measured C_v is given by (2)

$$\frac{\Delta C_v}{R} \left(\frac{n}{V_{\text{Total}}} > \rho_c \right) = \Delta C_{v3} ,$$

$$= [C_{v3} (2 \text{ phases}) - C_{v3} (1 \text{ phase})] ,$$

$$= \frac{T}{\rho_3^2} P_{\rho(3)} \left(\frac{d\rho_3}{dT} \right)^2 \quad (364)$$

or, in terms of reduced variables,

$$\frac{\Delta C_v}{R} \left(\frac{n}{V_{\text{Total}}} > \rho_c \right) = \frac{\Delta C_{v3}}{R} ,$$

$$= \frac{[C_{v3} (2 \text{ phases}) - C_{v3} (1 \text{ phase})]}{R} ,$$

$$= \frac{Z_c \gamma \beta_{\alpha(3)} (\alpha'_3)^2}{\alpha_3^2} . \quad (365)$$

Since β_{α} at saturation is always greater than zero, except at the critical point, then we see from equations 363 and 365 that the

two-phase heat capacity at constant volume is always greater than the single-phase heat capacity, except perhaps at the critical point.

Values of $\frac{\Delta C_{v1}}{R}$ and $\frac{\Delta C_{v3}}{R}$ as a function of γ are listed in table

71. These same data are illustrated in figures 112 and 113.

FIGURE 112. - Redlich-Kwong fluid, discontinuities in the measured heat capacities at constant volume in passing from two phases present in the calorimeter to a single phase as a function of temperature.

FIGURE 113. - Redlich-Kwong fluid, discontinuities in the measured heat capacities at constant volume in passing from two phases present in the calorimeter to a single phase as a function of temperature near the critical point.

In a previous paper (1), it is shown that

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha \rightarrow 1}} \frac{\Delta C_{\gamma}}{R} = \frac{3A^2 Z_c}{2B},$$

$$= \frac{3Z_c (\beta_{\alpha\gamma})_{c.p.}^2}{(\beta_{\alpha\alpha})_{c.p.}} \quad (366)$$

For a Redlich-Kwong fluid, we then have from equations 23, 178, 179, and 366,

$$\lim_{\substack{\gamma \rightarrow 1 \\ \alpha \rightarrow 1}} \frac{\Delta C_{\gamma}}{R} = 10.4901 \quad (367)$$

TABLE 71. - REDLICH-KWONG FLUID, DISCONTINUITIES IN THE MEASURED HEAT CAPACITIES AT CONSTANT VOLUME IN PASSING FROM TWO PHASES PRESENT IN THE CALORIMETER TO A SINGLE PHASE AS A FUNCTION OF TEMPERATURE

$$\gamma = T/T_c$$

$$\Delta C_v = C_v (2 \text{ phases}) - C_v (1 \text{ phase})$$

γ	$\frac{\Delta C_{v1}}{R}$	$\frac{\Delta C_{v3}}{R}$
0.00000E-99	+ ∞	2.25000E+00
1.00000E-01	2.58271E+04	2.29450E-00
1.50000E-01	7.53000E+03	2.33377E-00
2.00000E-01	3.11491E+03	2.38290E-00
2.50000E-01	1.55850E+03	2.44243E-00
3.00000E-01	8.78333E+02	2.51355E-00
3.50000E-01	5.36718E+02	2.59813E-00
4.00000E-01	3.47639E+02	2.69883E-00
4.50000E-01	2.35403E+02	2.81901E-00
5.00000E-01	1.65326E+02	2.96244E-00
5.50000E-01	1.19869E+02	3.13304E-00
6.00000E-01	8.94097E+01	3.33510E-00
6.50000E-01	6.83582E+01	3.57394E-00
7.00000E-01	5.33522E+01	3.85709E-00
7.50000E-01	4.23156E+01	4.19608E-00
8.00000E-01	3.39326E+01	4.60968E-00
8.50000E-01	2.73368E+01	5.13129E-00
9.00000E-01	2.19127E+01	5.82946E-00
9.50000E-01	1.71059E+01	6.89113E-00
9.52000E-01	1.69158E+01	6.94795E-00
9.54000E-01	1.67252E+01	7.00650E-00
9.56000E-01	1.65338E+01	7.06690E-00
9.58000E-01	1.63415E+01	7.12929E-00
9.60000E-01	1.61482E+01	7.19381E-00
9.62000E-01	1.59537E+01	7.26063E-00
9.64000E-01	1.57577E+01	7.32996E-00
9.66000E-01	1.55601E+01	7.40202E-00
9.68000E-01	1.53606E+01	7.47706E-00
9.70000E-01	1.51588E+01	7.55539E-00
9.72000E-01	1.49545E+01	7.63736E-00
9.74000E-01	1.47471E+01	7.72338E-00
9.76000E-01	1.45361E+01	7.81395E-00
9.78000E-01	1.43210E+01	7.90969E-00
9.80000E-01	1.41009E+01	8.01134E-00
9.82000E-01	1.38750E+01	8.11987E-00
9.84000E-01	1.36419E+01	8.23648E-00
9.86000E-01	1.34001E+01	8.36282E-00
9.88000E-01	1.31472E+01	8.50113E-00
9.90000E-01	1.28801E+01	8.65466E-00
9.92000E-01	1.25936E+01	8.82840E-00
9.94000E-01	1.22795E+01	9.03078E-00
9.96000E-01	1.19211E+01	9.27831E-00
9.98000E-01	1.14756E+01	9.61379E-00
9.99000E-01	1.11744E+01	9.86033E-00
1.00000E-00	1.04901E+01	1.04901E+01

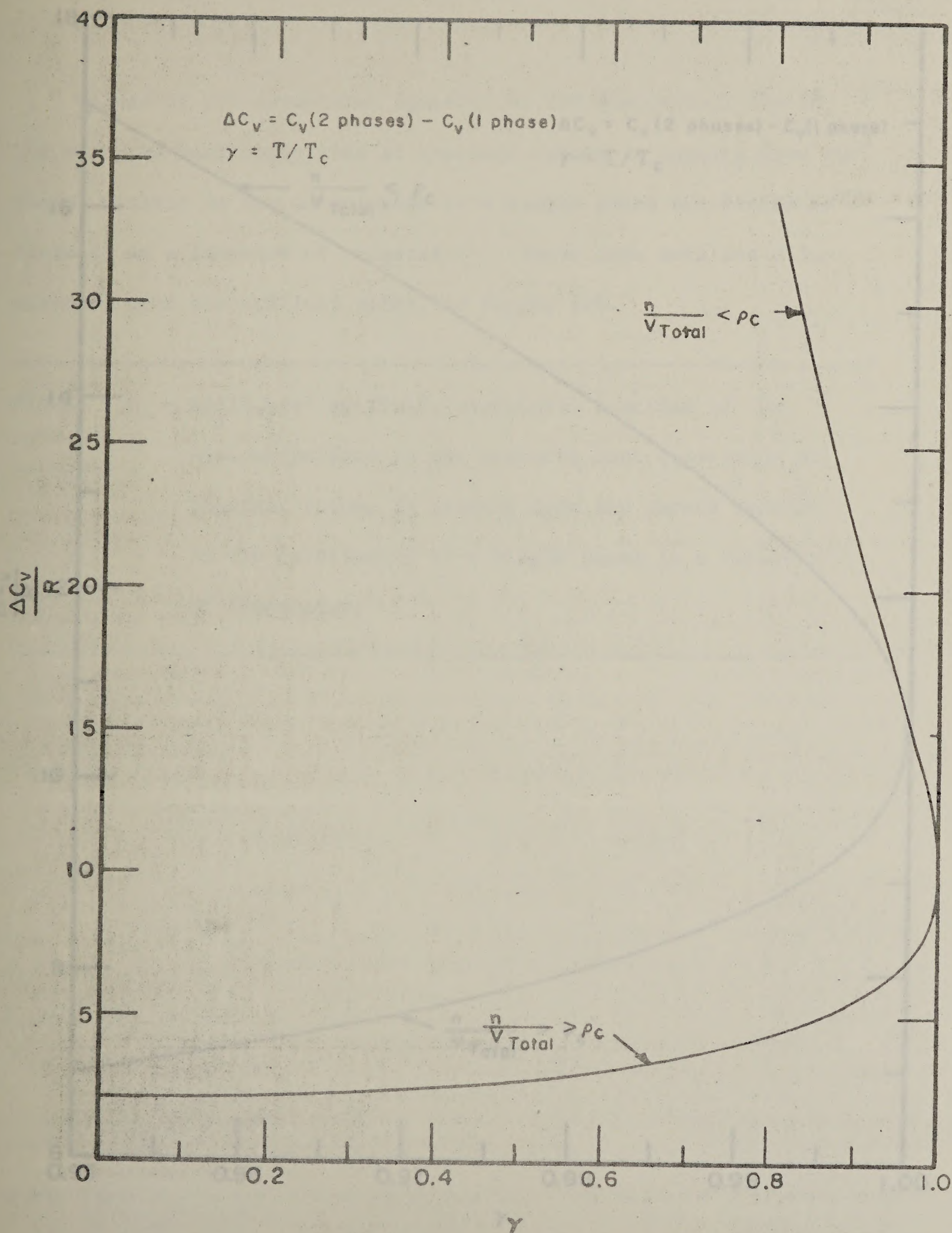


FIGURE 112.—Redlich-Kwong Fluid, Discontinuities in the Measured Heat Capacities at Constant Volume in Passing from Two Phases Present in the Calorimeter to a Single Phase as a Function of Temperature.

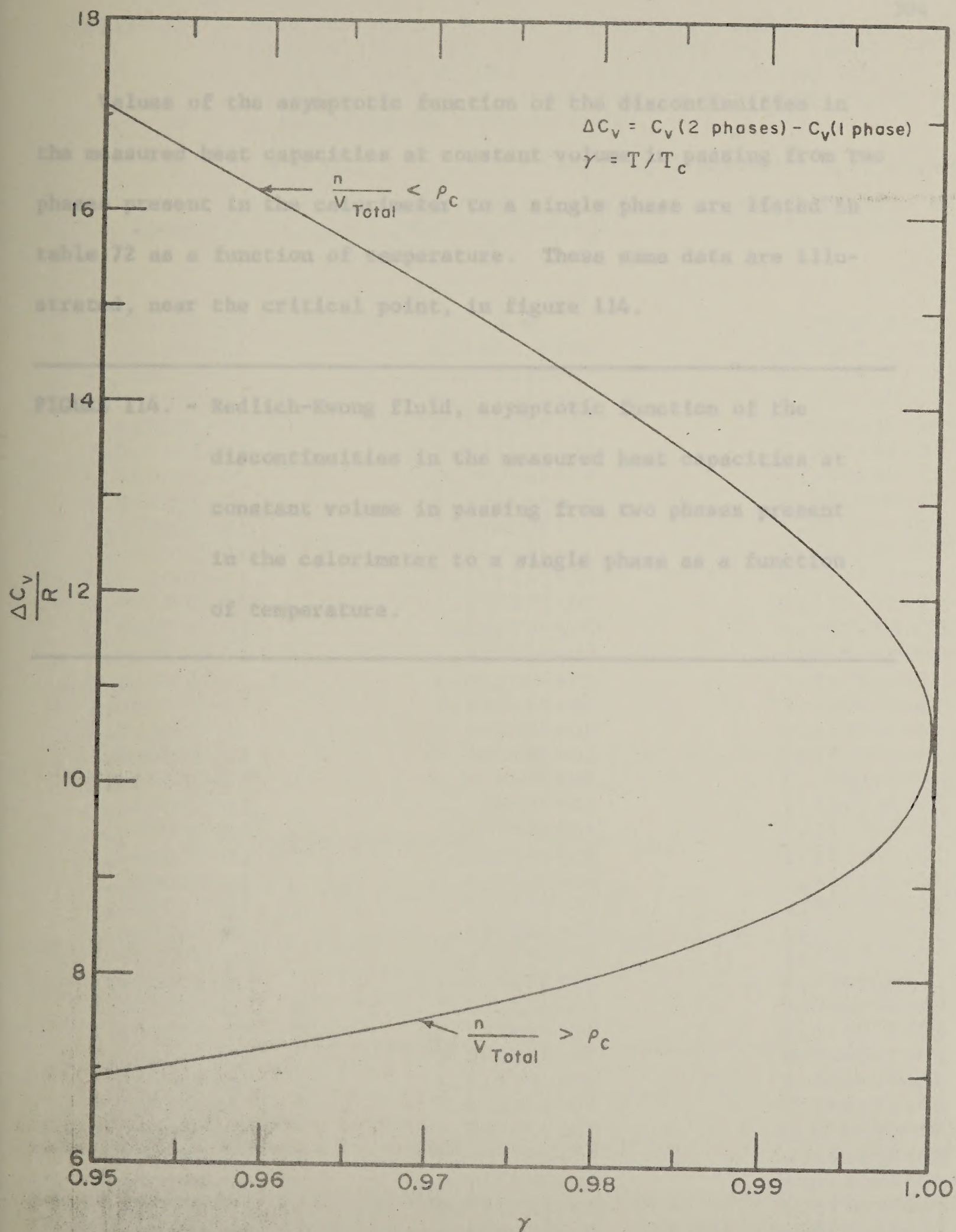


FIGURE 113.—Redlich-Kwong Fluid, Discontinuities in the Measured Heat Capacities at Constant Volume in Passing from Two Phases Present in the Calorimeter to a Single Phase as a Function of Temperature Near the Critical Point.

FIGURE 114. - Redlich-Kwong fluid, asymptotic function of the discontinuities in the measured heat capacities at constant volume in passing from two phases present in the calorimeter to a single phase as a function of temperature.

TABLE 72. - REDLICH-KWONG FLUID, ASYMPTOTIC FUNCTION OF THE DISCONTINUITIES IN THE MEASURED HEAT CAPACITIES AT CONSTANT VOLUME IN PASSING FROM TWO PHASES PRESENT IN THE CALORIMETER TO A SINGLE PHASE AS A FUNCTION OF TEMPERATURE

$$\gamma = T/T_c$$

$$\Delta C_V = C_V (2 \text{ phases}) - C_V (1 \text{ phase})$$

$$(1-\gamma) \left[\frac{\Delta C_{V_1} - (\Delta C_V)_{c.p.}}{R} \right]^2 \quad \left[\frac{\Delta C_{V_3} - (\Delta C_V)_{c.p.}}{R} \right]^2$$

1.000000E-00	+ ∞	6.79005E+01
9.000000E-01	6.66501E+08	6.71691E+01
8.500000E-01	5.65431E+07	6.65268E+01
8.000000E-01	9.63746E+06	6.57278E+01
7.500000E-01	2.39635E+06	6.47662E+01
7.000000E-01	7.53152E+05	6.36266E+01
6.500000E-01	2.76916E+05	6.22843E+01
6.000000E-01	1.13669E+05	6.07050E+01
5.500000E-01	5.05860E+04	5.88468E+01
5.000000E-01	2.39743E+04	5.66668E+01
4.500000E-01	1.19638E+04	5.41274E+01
4.000000E-01	6.22829E+03	5.11951E+01
3.500000E-01	3.34871E+03	4.78343E+01
3.000000E-01	1.83715E+03	4.39978E+01
2.500000E-01	1.01286E+03	3.96156E+01
2.000000E-01	5.49548E+02	3.45802E+01
1.500000E-01	2.83809E+02	2.87176E+01
1.000000E-01	1.30475E+02	2.17222E+01
5.000000E-02	4.37688E+01	1.29531E+01
4.800000E-02	4.12897E+01	1.25473E+01
4.600000E-02	3.88755E+01	1.21359E+01
4.400000E-02	3.65254E+01	1.17187E+01
4.200000E-02	3.42384E+01	1.12955E+01
4.000000E-02	3.20137E+01	1.08660E+01
3.800000E-02	2.98504E+01	1.04299E+01
3.600000E-02	2.77477E+01	9.98694E+00
3.400000E-02	2.57050E+01	9.53669E+00
3.200000E-02	2.37216E+01	9.07884E+00
3.000000E-02	2.17969E+01	8.61295E+00
2.800000E-02	1.99303E+01	8.13856E+00
2.600000E-02	1.81215E+01	7.65517E+00
2.400000E-02	1.63699E+01	7.16217E+00
2.200000E-02	1.46755E+01	6.65890E+00
2.000000E-02	1.30379E+01	6.14460E+00
1.800000E-02	1.14573E+01	5.61836E+00
1.600000E-02	9.93384E+00	5.07912E+00
1.400000E-02	8.46787E+00	4.52562E+00
1.200000E-02	7.06016E+00	3.95628E+00
1.000000E-02	5.71186E+00	3.36911E+00
8.000000E-03	4.42479E+00	2.76151E+00
6.000000E-03	3.20180E+00	2.12984E+00
4.000000E-03	2.04759E+00	1.46861E+00
2.000000E-03	9.71184E-01	7.68057E-01
1.000000E-03	4.68247E-01	3.96707E-01
0.000000E-99	0.000000E-99	0.000000E-99

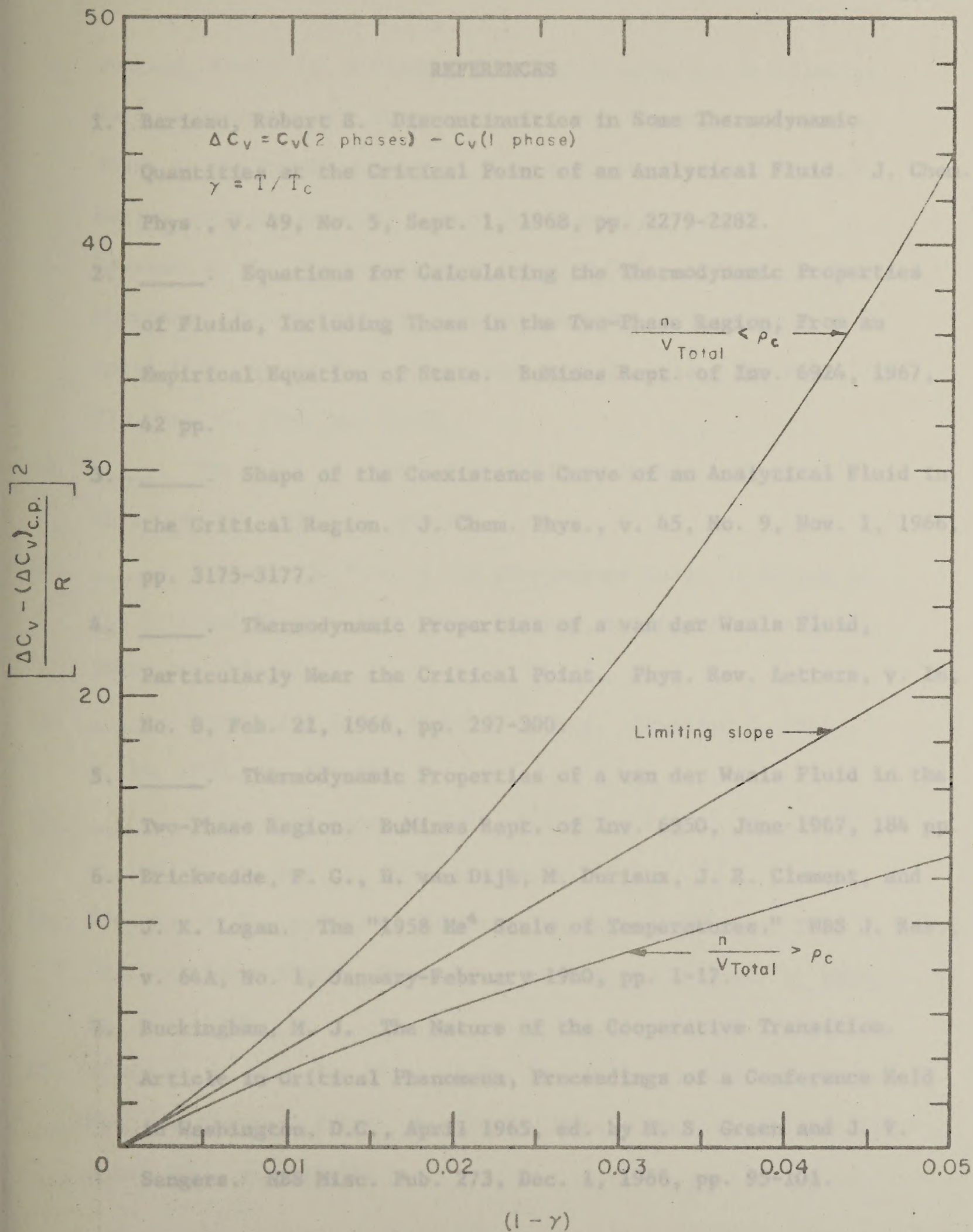


FIGURE 114.—Redlich-Kwong Fluid, Asymptotic Function of the Discontinuities in the Measured Heat Capacities at Constant Volume in Passing from Two Phases Present in the Calorimeter to a Single Phase as a Function of Temperature.

REFERENCES

1. Barieau, Robert E. Discontinuities in Some Thermodynamic Quantities at the Critical Point of an Analytical Fluid. *J. Chem. Phys.*, v. 49, No. 5, Sept. 1, 1968, pp. 2279-2282.
2. _____. Equations for Calculating the Thermodynamic Properties of Fluids, Including Those in the Two-Phase Region, From an Empirical Equation of State. BuMines Rept. of Inv. 6924, 1967, 42 pp.
3. _____. Shape of the Coexistence Curve of an Analytical Fluid in the Critical Region. *J. Chem. Phys.*, v. 45, No. 9, Nov. 1, 1966, pp. 3175-3177.
4. _____. Thermodynamic Properties of a van der Waals Fluid, Particularly Near the Critical Point. *Phys. Rev. Letters*, v. 16, No. 8, Feb. 21, 1966, pp. 297-300.
5. _____. Thermodynamic Properties of a van der Waals Fluid in the Two-Phase Region. BuMines Rept. of Inv. 6950, June 1967, 184 pp.
6. Brickwedde, F. G., H. van Dijk, M. Durieux, J. R. Clement, and J. K. Logan. The "1958 He⁴ Scale of Temperatures." *NBS J. Res.*, v. 64A, No. 1, January-February 1960, pp. 1-17.
7. Buckingham, M. J. The Nature of the Cooperative Transition. Article in *Critical Phenomena, Proceedings of a Conference Held in Washington, D.C., April 1965*, ed. by M. S. Green and J. V. Sengers. NBS Misc. Pub. 273, Dec. 1, 1966, pp. 95-101.

8. Douglas, Edward L. A General Computer Program for Calculating Various Thermodynamic Properties of a Pure Material, Including Those in the Two-Phase Region, From A Single Equation of State. Helium Activity Internal Report (in process).
9. Edwards, M. H. The Coexistence Curve of He^4 . Article in Critical Phenomena, Proceedings of a Conference Held in Washington, D.C., April 1965, ed. by M. S. Green and J. V. Sengers. NBS Misc. Pub. 273, Dec. 1, 1966, pp. 82-85.
10. _____. The Index of Refraction of Liquid Helium. Canadian J. Phys., v. 34, 1956, pp. 898-900.
11. _____. Nonanalytic Form of the Coexistence Curve of Helium at the Critical Point. Phys. Rev. Letters, v. 15, No. 8, Aug. 23, 1965, pp. 348-351.
12. _____. Refractive Index of He^4 : Liquid. Canadian J. Phys., v. 36, 1958, pp. 884-898.
13. _____. Refractive Index of He^4 : Saturated Vapor. Phys. Rev., v. 108, No. 5, Dec. 1, 1957, pp. 1243-1245.
14. Edwards, M. H., and W. C. Woodbury. Saturated He^4 Near Its Critical Temperature. Phys. Rev., v. 129, No. 5, Mar. 1, 1963, pp. 1911-1918.
15. Gitterman, M. Sh. The Shape of the Liquid-Gas Coexistence Curve Near the Critical Point. Russian J. Phys. Chem., v. 39, No. 4, April 1965, pp. 522-524.

16. Griffiths, Robert B. Power Series Expansions and Specific-Heat Singularities Near the He^4 Critical Point. *Phys. Rev. Letters*, v. 16, No. 18, May 2, 1966, pp. 787-788.
17. Landau, L. D., and E. M. Lifshitz. *Statistical Physics*. Transl. by E. Peierls and R. F. Peierls, Addison-Wesley Publishing Company, Inc., Reading, Mass., 1958, 484 pp.
18. Lewis, G. N., and M. Randall. *Thermodynamics and the Free Energy of Chemical Substances*. McGraw-Hill Book Company, Inc., New York, 1923, 653 pp.
19. Mistura, L., and D. Sette. Shape of the Coexistence Curve in the Critical Region. *Phys. Rev. Letters*, v. 16, No. 7, Feb. 14, 1966, pp. 268-270.
20. Partington, J. R. *An Advanced Treatise on Physical Chemistry*. I. Fundamental Principles. The Properties of Gases. John Wiley and Sons, Inc., New York, 1962, 943 pp.
21. Redlich, Otto, and J. N. S. Kwong. On the Thermodynamics of Solutions. V. An Equation of State. Fugacities of Gaseous Solutions. *Chem. Rev.*, v. 44, No. 1, February 1949, pp. 233-244.
22. Roach, Pat R., and D. H. Douglas, Jr. Coexistence Curve of He^4 Near the Critical Point. *Phys. Rev. Letters*, v. 17, No. 21, Nov. 21, 1966, pp. 1083-1086.
23. Sherman, Robert H. Behavior of He^3 in the Critical Region. *Phys. Rev. Letters*, v. 15, No. 4, July 26, 1965, pp. 141-142.

24. Tisza, Laszlo, and C. E. Chase. Equation of State of ^4He in the Critical Region. *Phys. Rev. Letters*, v. 15, No. 1, July 5, 1965, pp. 4-6.

